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THE
FARMER'S MANUAL
OF
AGRICULTURAL
CHEMISTRY.

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John B. Fessenden, M.D.
of
Jamaica Plain.
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John Bumstead Fessenden.

THE

FARMER'S MANUAL

OF

Agricultural Chemistry,

WITH

INSTRUCTIONS RESPECTING THE DISEASES OF CEREALS,

AND

THE DESTRUCTION OF THE INSECTS WHICH ARE
INJURIOUS TO THOSE PLANTS.

Alphonse (René BY Le Mire)
A. NORMANDY,

AUTHOR OF "THE COMMERCIAL HAND-BOOK OF CHEMICAL ANALYSIS," OF "PRACTICAL INTRODUCTION TO ROSE'S CHEMISTRY," AND EDITOR OF ROSE'S "TREATISE OF CHEMICAL ANALYSIS," ETC., ETC.

ILLUSTRATED BY NUMEROUS WOOD ENGRAVINGS.

LONDON:
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Bequest of
John Bumstead Fessenden, B.S.,
of Jamaica Plain.

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PREFACE.

UNTIL a comparatively recent period agriculture may be said to have been scarcely anything more than a mere manual art, the practice of which was limited to the almost servile observance of certain empirical rules, the result of the experience of ages, but too often applied without intelligence or discrimination.

This stationary condition of an art which dates from the remotest times on record was due, on the one hand, to the want of education on the part of the cultivators of the soil, who could not understand, and were perfectly unable to investigate, the rationale of agricultural operations discovered by chance and consecrated by usage; and, on the other hand, to a deficiency in the means of acquiring the necessary knowledge, for the sciences which bear directly upon agriculture were then either unborn or in their infancy; or else being cultivated exclusively as independent sciences, they remained altogether in the hands of the savans, who besides, in former days, cared but little about making themselves intelligible to the profane. Science had not been popularised.

Sixty years ago the connexion which exists between chemistry and agriculture was scarcely suspected, or if suspected by a few minds of unusual shrewdness, it was more intuitively, so to speak, than otherwise; at any rate the means by which the connexion might be traced were deficient, as well as the knowledge of the processes by which it could be brought into practical use.

The admirable lectures delivered by Sir H. Davy before the Board of Agriculture, from 1802 to 1812, may be said to have created a new era in agricultural matters, and the advancement of that department of human knowledge may be dated from that time. He it was who first gave the impulse, first diffused light into that chaos, first reduced it to a regular and systematic form, which has since been so much extended and improved, more especially within the last few years by the labours of Liebig, Boussingault, Payen, Johnston, and other eminent chemists.

The works, however, in which their researches and observations are consigned, are either too theoretical to be understood by the majority even of well informed readers, or take a wider range than may be wanted for immediate and practical purposes. Professor Johnston's excellent and much esteemed book, "Elements of Agricultural Chemistry and Geology," is a popular treatise on the principles of these two sciences; but, as in most of the other books to which I have been alluding, it does not give, nor does it profess to do so, any practical directions on the means of determining the composition of arable lands, of ascertaining the presence of the constituents which are necessary for the culture of particular crops, of analyzing manures, &c. &c. It is this want which, at the request of Messrs. Knight and Sons, I have endeavoured to supply, and it is for the candid reader to decide how far I have been successful in the accomplishment of that task.

Amongst the persons engaged in agricultural operations, many, I know, are possessed of considerable chemical knowledge, wherefore it is not for them that this little book has been written, though possibly, even they may find here and there a useful hint, or be reminded of things for the moment forgotten ; others, however, and it is the largest number, are ignorant of chemistry, or but moderately conversant with that science, it is to them that the present work is more especially dedicated ; and in order, as much as possible, to adapt it to various requirements, I have devoted Chapter IV. to the description of the simple tests by which the presence of the ingredients of soils may be recognized, and have related in Chapter V. the methods by which the relative amount or proportion of these ingredients can be approximatively determined ; whilst Chapter VI. contains practical instructions for the more regular and precise analysis of soils.

Lastly, with a view to render the work still more useful to the Farmer, I have been induced to add two chapters which were not originally contemplated ; one is, on the principal Diseases of Cereals ; the other, on the insects which are injurious to those plants, with the curative or preventive methods for both plagues. And I may say that, although that portion of the book is scarcely anything else than a compilation, yet it has proved to me the most arduous task, and that which has consumed most of my time in getting it up.

The works from which I have mostly borrowed the requisite information are, Sir J. Banks's Short Account on the Disease in Corn; L'Abbé Tessier, Traité des Maladies des Grains; Mathieu Tillet, Dissertation sur la Cause qui Corrompt les Grains de Blé; The Quarterly Journal of Agriculture; Giradin et Dubreuil, Elements of Agriculture; The Gardener's Magazine; F. Curtis's Catalogue of the Plants growing Wild in the Environs of London; Köllar's Treatise on Insects injurious to Vegetation; Stephens's Illustrations of British Entomology; Germar, Magazin der Entomologie; Latreille's Historie Naturelle; Westwood's British Moths; Cuvier, on Insects; Dr. Giuseppe, Gené Sugli Insetti piu noscivi alla Agricoltura; Bonaventura Corti, Storia Naturale diquegli Insetti che rodono le Piantine del frumento in Erba, &c. &c.

A. NORMANDY.

67, Judd Street, Brunswick Square.

PUBLISHER'S NOTE.

The whole of the following pages were in type as far back as October, 1851, but from press of business the Publishers were unable to issue them to the Public until now, and although they are not aware of anything having been published that could supersede the contents of this work, still, in justice to the Author, they think it right to append this note.

CONTENTS.

CHAPTER I.

Introduction — Observations on Agricultural Chemisty — The Food of Plants . . . . Page 1

CHAPTER II.

Organic and Inorganic Substances — Soils, Subsoils, and Vegetable Soils—Their Formation—Origin of Humus, or Mould—Composition of Arable Lands ; their Distinctive Characters — Free, stiff or clayey, chalky, marly, light, or sandy, humous Soils—Plants which grow spontaneously on them—Classification of Soils 3

CHAPTER III.

On the Soluble and Insoluble Constituents of Soils which are necessary to the Growth of Plants—What Plants are best suited for certain Soils—Soluble and Insoluble Ingredients of Plants—Potash—Plants—Lime Plants—Silica—Plants 17

CHAPTER IV.

Outline of the Properties of the Ingredients of Soils—Clay—Its quantity in good arable land—Its Influence on Plants—Lime Stone or Chalk—Quick Lime—Marl—Magnesia—Sand, or Silica—Oxydes of Iron and of Manganese—Sulphur—Ammonia and Ammoniacal Salts—Copperas—Common Salt—Phosphates — Sulphates — Organic Matter—Use and Abuse, Application and Effects of these Various Substances on Soils — Simple Tests by which their Presence may be detected . 25

CHAPTER V.

Simple Methods by which the Relative Proportions of the chief Ingredients of Soils may be ascertained—How to determine the Proportions of Moisture, of Clay, of Lime, of Humus and of Sand, contained in Soils—Determination of the Specific Gravity of Soils—Their Capillarity, and power of Absorbing and Retaining Water 44

CHAPTER VI.

How to Ascertain whether a soil is fit for the Culture of Particular Crops—Practical Instructions for the Regular and Precise Analysis of Soils—Analysis of the Substances in the Soil which are Soluble or Insoluble in Water, or in Acids—Examination of the particular Forms of Organic Matter present in a Soil 59

CHAPTER VII.

Chemical Methods of maintaining, increasing, or restoring the Fertility of Soils—On Manures—Vegetable, Animal, and Vegeto-Animal or Mixed Manures—Farm-yard Manure—Guano—Composts—Inorganic, Saline or Mineral Manures—Classification and Use of Manures . 96

CHAPTER VIII.

Analysis of Manures—Of Guano—Relative Value of Manures . 124

DISEASES OF CEREALS.

	PAGE		PAGE
Mildew . . .	145	Canker . . .	159
Smut . . .	151	Ergot, or Spur . .	165

INSECTS INJURIOUS TO CEREALS.

	PAGE		PAGE
The Common Cockchafer .	173	The Ground Beetle .	187
The Field Cockchafer .	173	The Common Dart Moth .	191
Slugs . . .	171	The Wheat Fly . .	193
The Wire Worm . .	175	The Wheat Midge . .	199
The Corn Weevil . .	177	The Mole Cricket . .	203
The Corn Moth, or Corn Worm	183	The Locust . .	206
Alucite . . .	184		

THE
FARMER'S MANUAL
OF
AGRICULTURAL CHEMISTRY.

CHAPTER I.

INTRODUCTION—OBSERVATIONS ON AGRICULTURAL CHEMISTRY.—THE FOOD OF PLANTS.

AGRICULTURE is the art of cultivating the ground, so that it may yield the various substances which serve as food to men and animals; and agricultural chemistry is the science which, in conjunction with those field operations which constitute the art of farming, teaches how to produce the greatest amount of these substances, of the best quality, and at least cost. To attain this object the agricultural chemist must inquire into the nature of soils, and of the plants which are grown upon them, with a view to ascertain which soils are best fitted, or whether, and how, they can be best fitted, in a practical manner, for the production or growth of such substances; how soils can be improved, or their fertility, and the quality of their produce permanently retained or increased.

It is not my intention in this work to treat of practical farming, but simply to explain, as clearly as I can, and in as popular a manner as possible, the different chemical manipulations and operations for the analysis of soils, and of manures, by which the operator may be enabled to ascertain whether the constituents which are necessary to render a soil productive are present in it, or in the manure intended to be applied to it, and in the proper degree.

Plants, in a sort of way, may be compared to animals; a certain quantity of food is necessary to their life, to their health, and general well-being, and for that purpose the food must be of the right kind, that is to say, must be such as may be easily assimilated, that is, taken in, and, so to speak, eaten and digested.

Although it would be wrong to believe that plants receive all their nourishment from the soil, yet the plants that are raised, or that grow upon it, bear a direct and immediate relation to the respective constituents contained in the soil, which can be taken up or appropriated by the plant; and as all the constituents or ingredients of a soil are not equally fitted for the well-being, or are not all in fact the proper food of every species of plant, since some plants refuse to take up, and leave untouched in the soil, certain substances or saline ingredients, which are, on the contrary, instantly selected by other plants as genial food, it follows that a plant may be as effectually starved by giving it improper, or unassimilable food, as by withholding it altogether, or by not restoring to the soil that which may have been removed by successive crops of the same product. If a soil be deficient in salts of lime, it will be useless to attempt the growth of peas, beans, and clover, for example, upon it; whilst the same soil, provided it contain a sufficient quantity of salts of potash, will support beet root, &c. It would therefore be as absurd to give potash, for example, to a plant which requires lime, as it would be to give meat to cattle instead of corn or hay.

To indicate to the farmer the methods by which he may know the constituents, or ingredients of his soil, and of the plants which he intends to grow upon it, is one of the main objects of the following chapters.

CHAPTER II.

ORGANIC AND INORGANIC SUBSTANCES — SOILS, SUBSOILS, AND VEGETABLE SOILS—THEIR FORMATION—ORIGIN OF HUMUS OR MOULD — COMPOSITION OF ARABLE LANDS, THEIR DISTINCTIVE CHARACTERS — FREE, STIFF, OR CLAYEY, CHALKY, MARLY, LIGHT, OR SANDY, HUMOUS SOILS—PLANTS WHICH GROW SPONTANEOUSLY ON THEM —CLASSIFICATION OF SOILS.

All substances in nature are divided into two great classes, namely, *organic* and *inorganic* substances. Those substances which belong to the animal, or to the vegetable kingdom, being organized, that is, living substances, or derived from living substances, are called *organic* bodies; the minerals, which are inert or inorganized substances, are called *inorganic* bodies.

Soils are the result of the disintegration of rocks. Disintegration means the action which rain and water-courses, frost and winds, exercise upon the solid rocks exposed to their influence, and in consequence of which they become gradually weathered, and more or less rapidly reduced into particles of various degrees of fineness. Streams of water abrade, or rub off the corners of stones and gravel, frost converts the water or moisture absorbed by rocks into an innumerable quantity of little wedges of ice which split and scatter them into fragments, and the hardest stones thus eventually crumble into dust. Soils consist of that dust.

If, taking a spade, we remove with it the loose earth or soil, we sooner or later reach a harder surface, which on examination will be found to be either *sand-stone*, *clay-stone*, or *lime-stone*. These rocks, lying under the soil, are called the *subsoil*, and as soils are the result of their disintegration, it follows that, generally speaking, if the subsoil be *sand*, *clay*, or *chalk*, the soil will be *sandy*, *clayey*, or *chalky;* or if the subsoil consists of all or only of two of these rocks, so will the soil partake and be a mixture of various proportions of these crumbled rocks. On plains, however, on valleys, and on slopes, the soil is sometimes formed not only by its own subsoil, but by that of the disintegrated rocks of more or less distant places which may have been carried to it by the agency of rivers, inundations, and other transporting causes. But although soils, at first, are nothing else than the dust of crumbling rocks, moistened by rains and dews, they afterwards are found to contain a certain quantity of decayed or decaying organic matter, derived from the seeds which have been deposited in it by nature's own mysterious and invisible hand, and which, dying on the spot, after a short lingering life, leave their remains to rot, and lay the foundation of a vegetable soil on which other plants again growing and dying bequeath a rich inheritance of organic matter, which thus in process of time accumulates in the soil, and eventually renders it fit for agricultural purposes.

This decayed organic matter, mixed with the soil, is called *humus* by chemists, and *mould* by every body. Yet *humus* and *mould*, although used as convertible terms even by the chemist, do not express exactly the same thing. *Humus*, strictly speaking, is a black, unctuous substance resulting, as we just said, from the decay of organic detritus, which, when dry, burns with a vegetable or empyreumatic odour, is insoluble, or nearly so, in water, and very soluble in alkalies. *Mould* is a mixture of *humus* with *earthy matter*. Humus is the principal cause of the fertility of all soils.

Sand, *clay*, *chalk*, and *mould*, are therefore the principal ingredients of arable soils, but their proportion is of course extremely variable, and according to the proportion of these constituents, the soils containing them are called *sandy*, *loamy*, *sandy loams*, *loamy sands*, *clay loams*, *strong clays*, *marly*, *chalky*, *humous*.

			Per cent.	
Sandy soils are those	which contain	not more than	10	of clay.
Sandy loams	ditto		20 to 30	ditto.
Loamy soils	ditto		30 to 50	ditto.
Clay loams	ditto		70 to 85	ditto.
Strong clay	ditto		85 to 95	ditto.
Marly soils	ditto		5 to 20	lime.
Chalky soils	ditto	more than	20	ditto.
Humous soils	ditto	do.	5	of humus.

Besides *sand*, *clay*, *lime*, and *humus*, arable soils contain also a small proportion of saline substances and metallic oxydes, of which we shall speak in due time.

Among the inorganic constituents of soils, some are *insoluble*, others are *soluble* in water; we shall examine these various substances in the next chapter.

Soils are sometimes divided into *free soils*, *stiff soils*, and *light soils*.

Free soils always have a dark colour, and are generally the best and most profitable to the farmer. Their dark or brown colour is, to a great extent, due to the large proportion of decayed organic matter, or *juice* of decayed organic matter, which they contain, and which is the result either of the natural accumulation of vegetable remains, as in the forests of America, or of the manure, roots, leaves, and stalks of vegetables which the farmer digs or ploughs in. Such soils are generally met with in lowlands or flats, and as they contain comparatively but little clay, they are easily ploughed and harrowed, both in dry and in wet weather.

Stiff or *clayey soils.* The soils in which clay (alumina) predominates, are called *clayey*, or *stiff* soils. As clay possesses the property of forming with water a plastic mass, that is, a mass which can be kneaded between the fingers into any shape, and of retaining water with great energy, forming with it a tenacious, close, and stiff paste, which takes a very long time to dry, clayey soils are sometimes excessively difficult to plough, and then produce dense, heavy clots which cannot be divided, except with great labour. Soils which contain a large proportion of that earth are not fit for agricultural purposes, for whilst they retain water with great tenacity, and do not allow it to percolate, they thus, in wet weather, become inundated; on the other hand, in dry weather, they become as it were set, and superficially very hard, both of which circumstances are exceedingly prejudicial to vegetation.

Clayey soils are, to a certain extent, characterized by the plants which grow spontaneously upon them; they are principally the following:—

Common Names.	Botanical Names.
Common coltsfoot .	Tussilago farfara.*
Dwarf elder . .	Sambucus ebulus.
Strong-scented lettuce	Lactuca virosa.
Wild chicory . .	Cichorium intybus.
Common bird's foot, or small horn trefoil .	Lotus corniculatus.
Greater bird's foot trefoil	Lotus major.
Tuberous rooted vetch	Orobus tuberosus.
Common birth wort .	Aristolochia vulgaris.
Couch grass . .	Triticum repens.
Fiorin	Agrostis stolonifera.

A stiff or clayey soil is besides easily recognized, because when an acid—for example, oil of vitriol, diluted with about twice its volume of water—is poured upon a portion of it, no effervescence, or only a very slight one, is produced.

If a portion of it be kneaded with a little water in the hands it will form a plastic paste, which being placed amongst burning coals will harden, and be converted into a hard compact mass resembling a brickbat.

Clayey soils often have a brown, a black, or a yellowish colour of greater or less intensity, which is due to the presence of a large proportion of iron in various degrees of oxydization. This brown or dark brown colour may therefore simulate the appearance of *free soils*, in which, as we said before, the brown colour is mainly due to a large proportion of organic matter. They may, however, be easily distinguished from each other by exposing a small portion of the soil upon a shovel to the action of the fire, for if the colour is due to the presence of iron, the soil on the red-hot shovel will assume a brick-red colour. Moreover, the specific gravity of these soils is much more considerable than that of those which contain much organic matter, as will be seen further on, where directions are given for taking specific gravities.

---

* This plant is characteristic, and always indicates a clayey soil.

M. Caillot discovered that the dark juice of dunghills is decolourized by clay, and that clay can attract, absorb, and retain or fix ammonia, which may be subsequently taken up by plants. Lastly, M. de Humboldt proved that clay soils have the precious property of absorbing the oxygen of the air, without a due supply of which all plants die.

The soils in which clay predominates are only fit for brick and tile making, or for the manufacture of pottery.

Marly soils. Clayey soils which are mixed with chalk, constitute *marly soils*, which often are most excellent; they produce a slight effervescence when an acid is poured upon them. Marly soils, which contain a proper quantity of chalk, of humus, &c., have a dark brown colour, and are easily managed. The clay which they contain enables them to retain the water which they have absorbed, as much and perhaps more than stiff or clayey soils, and the plants which grow upon them are thus supplied with a degree of moisture which greatly promotes their growth, though in rainy weather, it often happens that, at a certain depth, the soil is on that account reduced to a perfectly liquid magma, which is greatly injurious; these soils can absorb the liquid and gaseous fertilizing agents contained in manures, and at the same time prevent their dispersion and waste.

Marly soils may to a certain extent be recognized from the plants which grow spontaneously upon them: they are principally the following:—

Common Names.	Botanical Names.
Common kidney vetch	Anthyllis vulneraria.
Wild or goose pansy	Potentilla anserina.
Creeping pansy	Potentilla reptans.
Common cinquefoil	
Purple melic-grass	Melica cerulea.
Strong-scented lettuce	Lactuca virosa.
Common soap-wort	Saponaria officinalis.
Sainfoin	Hedysarum onobrychis.
Carex (several species)	Carex.
Common gum succory	Chondrilla juncea.
Yellow meadow-rue	Thalictrum flavum.
Ash-tree	Fraxinus.

What we have just said refers only to such soils as contain a pretty large quantity of clay, for if carbonate of lime is in greater proportion, they approximate chalky soils, more or less, and may be subject to all the defects of that description of land.

Chalky soils are soils, as we said before, in which *chalk* or *lime-stone* (carbonate of lime) predominates. They have a whitish or drab colour, produce a strong effervescence when treated by acids, and dissolve almost without residue in muriatic acid. As chalky soils have a light colour, it follows that the solar rays are reflected, so that whilst, on the one hand, the heat does not penetrate into the ground, the surface, on the other hand, is scorched up by their reverberation, hence a doubly injurious effect to which vegetation is exposed on such lands, which are thus rendered almost unfit for agricultural purposes, except they be mixed with other soils, in which case they are easily managed, and often constitute excellent soils, at least for certain plants. Generally speaking, however, they are not liked by the farmer; yet, if the quantity of lime is not too considerable, they may be rendered available for lucern, sainfoin, clover, &c.; but an excess of lime soon decreases their value, and if humus is deficient they require much manure.

The principal plants which grow spontaneously on calcareous or chalky soils are the following:—

Common Names.	Botanical Names.
Common Burnet Saxifrage .	Pimpinella saxifraga.
Sage, or wild clary . . .	Salvia verbenaca.
Hairy violet	Viola hirta.
Blue sesleria, or moor grass .	Sesleria cœrulea.
Common corn poppy . .	Papaver rhœas.
Clustered bell-flower . .	Campanula glomerata.
Least mountain bed straw .	Galium pusillum.
Common Cromwell . . .	Lithospermum officinale.
Corn bell flower . . .	Campanula hybrida.
White Mullein . . .	Verbascum Lychnitis.
Great Mullein . . .	Verbascum Thapsus.
Common Barbary . . .	Berberis vulgaris.
Common Basil thyme . .	Acinos vulgaris.
Mealy guelder rose . . . Wayfaring tree . . .	Viburnum lantana.
Spring cinquefoil . .	Potentilla verna.
Common bramble or blackberry	Rubus fructicosus.
Dewberry	Rubus cæsius.
Pasque flower	Anemone pulsatilla.
Common travellers' joy . .	Clematis vitalba.
Common sun-cistus . .	Helianthemum vulgare.
Great flowered self-heal . .	Prunella grandiflora.
Musk thistle	Carduus nectans.
Woolly-headed plume thistle .	Cnicus eriophorus.
Dwarf plume thistle . .	Cnicus acaulis.
Common cotton thistle . .	Onopordum Acanthium.
Common carline thistle . .	Carlina vulgaris.
Strong-scented, or wild lettuce	Lactuca virosa.
Common sainfoin . . .	Onobrychis sativa.*

---

* This is a characteristic plant; where met with, the soil is almost invariably calcareous.

Common Names.	Botanical Names.
Lesser yellow trefoil . .	Trifolium filiforme.
Common juniper . . .	Juniperus communis.
Common, or spring rest-harrow	Ononis spinosa.
Common ash-tree . . .	Fraxinus.
Common hazel-nut . . .	Corylus avellana.
Common coltsfoot . . .	Tussilago farfara.
Dyer's weed	Reseda luteola.
Hoary plantain . . .	Plantago media.
Common sun cistus . .	Helianthemum vulgare.
Speedwell-leaved whitlow grass	Draba muralis.

Light or sandy soils, are those in which sand (*silica*) predominates. Pure sand is white, but that of sandy soils is generally coloured by peroxyde of iron (rust) or humus, and mixed with clay and chalk. Sandy soils are the worst; for as sand does not retain water, the plants are soon dried up; these soils require, moreover, a larger proportion of manure than others.

Sandy soils, therefore, when they contain much sand, are of little or no value to the farmer; but when mixed with proper quantities of clay, of chalk, and of humus, they may become very valuable, are easily ploughed both in dry and wet weather, and all kind of produce may thus, by proper management, be grown upon them.

The plants which grow spontaneously upon sandy soils are the following:—

Common Names.	Botanical Names.
Grey hairy grass . . .	Aira canescens.
Silky-bent grass . . .	Agrostis spica venti.
Silver hair grass . . .	Aira caryophyllea.
Common seaweed . . .	Ammophylla arundinacea.
Upright sea-lyme grass . .	Elymus arenarius.
Creeping fescue grass . .	Festuca rubra.
Barren ditto	Ditto bromoides.
Cat's-tail grass . . .	Phleum arenarium.
Trifid speedwell . . .	Veronica triphyllos.
Vernal ditto	Ditto verna.
Wall ditto	Ditto arvensis.

Common Names.	Botanical Names.
Common viper's bugloss	Echium vulgare.
Common sheep's scabious	Jasione montana.
Buck's horn plantain	Plantago coronopus.
Common thrift	Statice armeria.
Purple sandwort	Arenaria rubra.*
Deptford pink	Dianthus armeria.
Sorrel	Oxalis acetosella.
Dyer's weed Yellow weed Wild woad Weld	Reseda luteola.
Rue-leaved saxifrage	Saxifraga tridactylites
Biting stone crop Wall-pepper	Sedum acre.
English catchfly	Silene Anglica.
Corn spurrey	Spergula arvensis.
Common carline thistle	Carlina vulgaris.
Thorny rest harrow Canmock Ground furze	Ononis spinosa.
Common birch	Betula alba.
Common and other carex	Carex arenaria.
Common chestnut	Castanea vulgaris.
Scotch fir	Pinus sylvestris.
Common basil thyme	Acinos vulgaris.
Common sun-cistus	Helianthemum vulgare.
Speedwell-leaved whitlow grass	Draba muralis.†
Long smooth-headed poppy	Papaver dubium.
Common red poppy	Ditto Rhœas.
Wild thyme	Thymus serpyllum.

The following table by M. Thaer and Einhoff exhibits the relative proportions of the elements of which the above-mentioned soils and their varieties consist.

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* This plant always indicates a poor sandy soil.

† The same as Arenaria rubra.

Name of soil.	Designation.	Clay.	Sand.	Chalk.	Humus.
Clayey (argillaceous)	Rich wheat land	74	10	4	11·5
do.	do.	81	6	4	8·5
do.	do.	79	10	4	6·5
Marly soil	do.	40	22	36	4
Light soil, with humus	Meadow land	14	49	10	27
Sandy soil, with humus	Rich barley land	20	67	3	10
Clayey soil	Good wheat land	58	36	2	4
Marly soil	Wheat land	56	30	12	2
Clayey soil	do.	60	38	...	2
Clayey soil	do.	48	50	...	2
Clay	do.	58	30	...	2
Clayey soil	Barley land, 1st class	38	60	...	2
do.	do. 2nd class	33	65	...	2
Sandy clay	do. do.	28	70	...	2
do.	Oats land	23·5	75	...	1·5
Clayey sand	do.	18·5	80	...	1·5
do.	Rye land	14	85	...	1
Sandy soil	do.	9	90	...	1
do.	do.	4	85	...	0·75
do.	do.	2	97·5	...	0·5

Humous soils.—This class includes peat, bog, turf, and marshes, which consist of fragments of undecomposed or partially decomposed vegetable fragments, of a peculiar kind of humus resulting from the subaqueous decomposition of vegetable matter, and contain free acids, that is, unsaturated acids, which render them incapable of supporting any other vegetables than those of an aquatic nature. The principal plants of which peat, bog, and marshes consist are the following:—

Common Names.	Botanical Names.
Common reed	Arundo phragmites.
Tall fescue grass	Festuca elatior.
Common mare's tail	Hippuris vulgaris.
Ivy-leaved duckweed and other duckweeds	Lemna trisulca.
Common butterwort	Pinguicula vulgaris.
Pale ditto	Ditto Lusitanica.
Wood club rush	Scirpus sylvaticus.

Common Names.	Botanical Names.
Greater hooded milfoil	Utricularia vulgaris.
Water speedwell	Veronica anagallis.
Pondweeds	Potamogeton.
Cross-leaved heath	Erica tetralyx.
Willow-herbs	Epilobium.
Common cranberry	Oxycoccus palustris.
Whortleberry Bilberry	Vaccinium myrtillus.
Common tormentil	Tormentilla officinalis.
Needle greenweed Ditto furze Petty whin	Genistra Anglica.
Flea carex	Carex pulicaris.
Soft brown ditto	Ditto intermedia.
Great rough and other carex	Ditto vulpina.
Spiked water milfoil	Myriophyllum spicatum.
Smooth horsetail	Equisetum limosum.
Corn horsetail	Ditto arvense.
Bog-moss	Sphagnum.
Confervas	Confervæ.
Common water horehound Gypsy wort	Lycopus Europæus.

&c. &c.

In their natural state, bogs and marshes are unfit for culture, but by draining, liming, and other operations, they may sometimes be converted into excellent lands for various crops, as will be seen further on.

In chapter V. we shall fully indicate and explain the processes by which a given soil may be referred to its place in the table of M. Schübler, which we are going to give, or in that of Messrs. Thaer and Einhoff which we have given before.

SCHUBLER'S CLASSIFICATION AND NOMENCLATURE OF SOILS, AS RECOMMENDED BY DR. DAUBENY.

(*From the Journal of the Royal Agricultural Society of England, Vol. III. p.* 156.)

Names of the Different Descriptions of Soil.			Proportions of Ingredients in every 100 Parts.				Agricultural Designations and general Relations with Reference to their Produce.*
Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.	
1. ARGILLACEOUS. Soils. — Above 50 per cent. of Clay. Not more than 5 per cent. of Lime.	Without Lime.	Poor	Above 50	0	0· to 0·5	The Remainder.	*Land for Wheat and Spelt.* The calcareous kinds not too rich in clay, and not too poor in sand and humus, give good returns, Wheat, spelt, barley, rape, beans, flax, and clover flourish in it especially. Those poor in humus are still suited for oats.
		Intermediate .	„ 50	0	0·5 to 1·5		
		Rich	„ 50	0	1·5 to 5·0	..	
	With Lime.	Poor	Above 50	0·5 to 5·0	0· to 0·5	..	
		Intermediate .	„ 50	0·5 to 5·0	0·5 to 1 5	..	
		Rich	„ 50	0·5 to 5·0	1·5 to 5·0	..	
2. LOAMY SOILS. — Not more than 50 nor less than 30 per cent. of Clay. Not more than 5 of Lime.	Without Lime.	Poor	30 to 50	0	0· to 0·5	..	*Land for Barley.* The soils which are rich in humus, and contain lime, are well suited even for wheat and spelt, and often approach nearly to the foregoing kinds. They are, moreover, suited for Triticum dicoccum (Emmer), one-grained wheat (Einkorn), rye, oats, rape (Reps), flax, and clover.
		Intermediate .	30 to 50	0	0·5 to 1·5	..	
		Rich	30 to 50	0	1·5 to 5·0	..	
	With Lime.	Poor	30 to 50	0·5 to 5·0	0· to 0·5	..	
		Intermediate .	30 to 50	0·5 to 5·0	0·5 to 1·5	..	
		Rich	30 to 50	0·5 to 5·0	1·5 to 5·0	..	
3. SANDY LOAMS. — Not more than 30 nor less than 20 per cent. of Clay. Not more than 5 of Lime.	Without Lime.	Poor	20 to 30	0	0· to 0·5	..	*Land for Barley and Oats.* Less suited for wheat and spelt than the former soils, but even better adapted for Triticum dicoccum and T. monococcum, as well as for rye Potatoes, turnips, and other roots thrive well in it.
		Intermediate .	20 to 30	0	0·5 to 1·5	..	
		Rich	20 to 30	0	1·5 to 5·0	..	
	With Lime.	Poor	20 to 30	0·5 to 5·0	0· to 0·5	..	
		Intermediate .	20 to 30	0·5 to 5·0	0·5 to 1 5	..	
		Rich	20 to 30	0·5 to 5·0	1·5 to 5·0	..	

* This of course chiefly applies to the soil and climate of Germany.

Names of the different Descriptions of Soil.			Proportions of Ingredients in every 100 Parts.				Agricultural Designations and general Relations with Reference to their Produce.
Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.	
4. SANDY LOAMS. — Not more than 20, nor less than 10 per cent. of Clay. Less than 5 per cent. of Lime.	Without Lime.	Poor	10 to 20	0	0· to 0·5	..	*Land for Oats and Rye.* Barley thrives well in those rich in humus. They are also well suited for buckwheat. Wheat, spelt, and clover, do not succeed.
		Intermediate .	10 to 20	0	0·5 to 1·5	..	
		Rich	10 to 20	0	1·5 to 5·0	..	
	With Lime.	Poor	10 to 20	0·5 to 5·0	0· to 0·5	..	
		Intermediate .	10 to 20	0·5 to 5·0	0·5 to 1·5	..	
		Rich	10 to 20	0·5 to 5·0	0·5 to 5·0	..	
5. SANDY SOILS. — Not more than 10 per cent. of Clay. Less than 5 per cent. of Lime.	Without Lime.	Poor	0· to 10	0	0· to 0·5	The Remainder.	*Land for Rye.* Of less value; often cultivated only every third year, and the poor land often not at all. Those containing humus are chiefly fit for buckwheat, oats, hemp, tobacco, potatoes, and spergula arvensis.
		Intermediate.	0· to 10	0	0·5 to 1·5		
		Rich	0· to 10	0	1·5 to 5·0	..	
	With Lime.	Poor	0· to 10	0·5 to 5·0	0· to 0·5	..	
		Intermediate.	0· to 10	0·5 to 5·0	0·5 to 1·5	..	
		Rich	0· to 10	0·5 to 5·0	1·5 to 5·0	..	
6. MARLY SOILS. — More than 5, not more than 20 per cent. of Lime.	Argillaceous	Poor	Above 50	5 to 20	0· to 0·5	..	Chiefly suited for wheat and spelt, together with lucern and sainfoin.
		Intermediate.	„ 50	5 to 20	0·5 to 1·5	..	
		Rich	„ 50	5 to 20	1·5 to 5·0	..	
	Loamy.	Poor	30 to 50	5 to 20	0· to 0·5	..	Less suited for wheat and spelt, more so for barley, Triticum dicoccum and T. monococcum, but are amongst the most fertile soils.
		Intermediate.	30 to 50	5 to 20	0·5 to 1·5	..	
		Rich	30 to 50	5 to 20	1·5 to 5·0	..	
	Belonging to the Sandy Loams.	Poor	20 to 30	5 to 20	0· to 0·5	..	Barley and Oats.
		Intermediate.	20 to 30	5 to 20	0·5 to 1·5	..	
		Rich	20 to 30	5 to 20	1·5 to 5·0	..	
	Belonging to the Loamy Sands.	Poor	10 to 20	5 to 20	0· to 0·5	..	Oats and Rye.
		Intermediate.	10 to 20	5 to 20	0·5 to 1·5	..	
		Rich	10 to 20	5 to 20	1·5 to 5·0	..	
	Humous.	Clayey . . .	Above 50	5 to 20	Above 5·0	..	The humous, and argillaceous, marly soils are amongst the best that exist.
		Loamy . . .	30 to 50	5 to 20	„ 5·0	..	
		Sandy . . .	20 to 30	5 to 20	„ 5·0	..	

Names of the Different Descriptions of Soil.			Preparations of Ingredients in every 100 Parts.				Agricultural Designations and general Relations with reference to their produce.
Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.	
7. CALCAREOUS SOILS. — Containing more than 20 per cent of Lime.	Argillaceous.	Poor . . .	Above 50	Above 20	0· to 0·5	The Remainder.	The argillaceous soils often approach in value to the argillaceous marls, the remaining orders of both these classes equally correspond one with the other; to the most valuable belongs, as in the former case, the humous. Those wanting in humus require much manure. Those rich in clay are well suited for spelt and wheat; oats; Triticum dicoccum, lucern, and sainfoin thrive in them. Their value is much decreased by containing an excess of lime.
		Intermediate	,, 50	,, 20	0·5 to 1·5		
		Rich . . .	,, 50	,, 20	1·5 to 5·0	..	
	Loamy.	Poor . . .	30 to 50	,, 2	0· to 0·5	..	
		Intermediate	30 to 50	,, 20	0·5 to 1·5	..	
		Rich . . .	30 to 50	,, 20	1·5 to 5·0	..	
	Belonging to the Sandy Loams.	Poor . . .	20 to 30	,, 20	0· to 0·5	..	
		Intermediate	20 to 30	,, 20	0·5 to 1·5	..	
		Rich . . .	20 to 30	,, 20	1·5 to 5·0	..	
	Belonging to the Loamy Sands.	Poor . . .	10 to 20	,, 20	0· to 0·5	..	
		Intermediate	10 to 20	,, 20	0·5 to 1·5	..	
		Rich . . .	10 to 20	,, 20	1·5 to 5·0	..	
	Sandy.	Poor . . .	0 to 10	,, 20	0· to 0·5	Any portion less than 80 per cent.	
		Intermediate	0 to 10	,, 20	0·5 to 1·5		
		Rich . . .	0 to 10	,, 20	1·5 to 5·0		
	Pure.	Poor . . .	0	,, 99	0· to 0·5	None.	
		Intermediate	0	,, 98	0·5 to 1·5	None.	
		Rich . . .	0	,, 94	1·5 to 5·0	None.	
	Humous.	Clayey. . .	Above 50	,, 20	Above 5·0	The Remainder.	
		Loamy . .	30 to 50	,, 20	,, 5·0		
		Sandy . .	20 to 30	,, 20	,, 5·0		
8. HUMOUS SOILS — Containing more than per cent. of Humus.	Soluble mild Humus.	Clayey. . .	Above 50	With or without Lime.	Above 5·0	..	The value of these soils is greatly augmented by admixture with lime. Those which contain lime and clay are suited for wheat, spelt, barley, and oleaginous plants; the loamy and sandy are especially adapted for oats, and in most places for wheat. The peaty and acid humous may be made fruitful by admixture with lime, sand, and clay.
		Loamy . .	30 to 50		,, 5·0	..	
		Sandy . .	20 to 30		,, 5·0	..	
	Insoluble carbonised or acid Humus.	Clayey. . .	Above 50	With or without Lime.	,, 5·0	..	
		Loamy . .	30 to 50		,, 5·0	..	
		Sandy . .	20 to 30		,, 5·0	..	
	Insoluble fibrous Vegetable Matter.	Bog and Peat Earth	With Lime		,, 5·0	..	
			Without Lime.		,, 5·0	..	

We said (page 5) that besides clay, sand, chalk, and mould, soils contained various saline and soluble substances, which, being dissolved by rains, are absorbed by the roots of plants. The above classifications, which do not take into account any of these constituents, cannot therefore be regarded as complete; but they are, however, extremely useful, because by means of the manipulations which will be described in the fifth chapter, the farmer may not only know what the principal constituents of good arable land are, but judge at once of the main deficiencies which must be supplied to ameliorate the constitutional quality of the soil and render it fit for culture. Thus, if a soil be found too clayey or tenacious, he may know what proportion of sand or of lime he must add to endow it with the properties he may wish for, or whether, or how far it is practicable for him to do so.

CHAPTER III.

ON THE SOLUBLE AND INSOLUBLE CONSTITUENTS OF SOILS WHICH ARE NECESSARY TO THE GROWTH OF PLANTS—WHAT PLANTS ARE BEST SUITED FOR CERTAIN SOILS—SOLUBLE AND INSOLUBLE INGREDIENTS OF PLANTS—POTASH-PLANTS—LIME-PLANTS—SILICA-PLANTS.

In the preceding chapter we said that amongst the constituents of soils, some were insoluble, and some were soluble in water. The insoluble ingredients, however, form by far the greatest portion of soils, since they generally amount, as may be seen by reference to Schübler's, or Thaer and Einhoff's table, to 95 per cent. of the whole mass. These insoluble ingredients are principally sand (*silica*), clay (*alumina*), lime-stone or chalk (*carbonate of lime*), to which must be added *peroxyde of iron* (rust), and certain substances resulting from the decomposition of vegetable matter or humus, and which are called *humine* and *ulmine*, and likewise such organic remains, twigs, roots, leaves, &c. which are as yet undecayed, and which when they exist in a greater proportion than 50 per cent. constitute *boggy* or *peaty soils.*

The soluble ingredients of soils are principally *common salt, plaster, Glauber's salt, Epsom salt, saltpetre* or *nitre, phosphates,* and *other salts of potash, of soda, of lime, and of magnesia.* The proportion of these soluble substances is very variable, but is always exceedingly small, and it is from them that plants derive their saline or mineral food; for plants, though called *organic bodies,* consist of both *organic* and *inorganic* elements. When a plant is burnt, the organic portion disappears, or goes off in smoke, and gases; but the inorganic portion, which is very small both in bulk and weight compared to the mass of the plant, is left as ashes.

This small proportion of saline matter which is thus detected in the ashes of plants, does not amount in the soil to more than from 30 to 100 grains in 10,000 grains. Yet "this quantity," observes Professor Johnston, "must not be considered too small to yield the whole supply which a crop requires, since *a single grain of saline matter in every pound of soil a foot deep, is equal to* 500 *pounds in an acre,* which is more than is carried from the soil in ten rotations (forty years) where only the wheat and barley are sent to market, and the straw and green crops are regularly, and without loss, returned to the land in the manure."

Since every plant, after being burnt, leaves invariably a certain quantity of ashes, it follows that the substances of which these ashes consist are not accidental, but indeed integrant and necessary parts of plants, necessary to their support or maintenance, health, life; they may be considered, so to speak, as the bones of plants; for example, the beautiful glossy varnish of wheat-straw, of cane, &c., is a coating of real glass, extracted and wrought out by the plant from the sand and potash contained in the soil: were these glass-making substances, namely, sand and potash, absent, the stalk would never grow up, support the weight of the ear, or resist the force of winds; it would droop, and sink down under a weight greater than its strength, and die.

Again, *phosphate of lime*, which is the principal constituent of the bones of animals, exists also in wheat, in barley, in turnips, and other vegetables, and in the same manner as they absorb this ingredient from the soil, so do animals, who feed upon them, derive from that source the material from which their bones are made, and which is no less essential to them than it is to the existence of the plant, though, in either case, it forms but a small part of the whole mass of the organized body.

The quantity of ashes left by the burning of plants varies, however, not only with every plant, but even in the different portions of the same plant, nay, in different portions of the same *part* of the plant. This fact was discovered by Professor Johnston, who found that by cutting a tall stalk of wheat, oats, or barley, into four equal parts, and burning each separately, the lowest portion left a greater quantity of ashes than the other parts, and so on in proportion, as follows: 8 or 9 per cent. for the lowest portion, 6 or 7 for the next, 5 or 6 for the third portion, and 3½ or 4 for the fourth portion, that is, for that portion farthest removed from the roots,—the top.

On the other hand, whilst 1000lbs. of clover hay, leave, after burning, 90 lbs. of ashes, the same quantity of oats leaves only 40 lbs.; of peas, 30 lbs.; of wheat, 20lbs.; of Indian corn, 15 lbs., &c. If, therefore, the farmer knows, on the one side, what quantity of soluble inorganic matter is available in his soil, and on the other, what quantity of mineral food (indicated by the ashes) is required by plants, it will not be difficult for him to manage matters so that the plants may be suited to his soil; for example, to grow on a soil, which may be poor in saline matter, only such plants which will do well and thrive upon that small quantity, that is, for the support of which that small quantity of mineral food is sufficient.

We now give in a tabular form the quantities of ashes yielded by 1000 parts in weight of the following plants.

	Sprengel.		Johnston.	
	Seed.	Straw.	Seed.	Straw.
Barley . .	23·49	52·42	about 30	about 50
Beans . .	21·36	31·21	„ 30	„ 50
Buckwheat	13·54	32·03	„ 30	„ „
Indian corn	„	„	„ 15	„ „
Linseed .	23·40	14·56	„ „	„ „
Oats . .	27·80	57·70	„ 40	„ 60
Peas . .	24·64	49·71	„ 30	„ 50
Rye . .	10·40	27·93	„ 20	„ 40
Wheat. .	17·77	35·18	„ 20	„ 50
	Roots.	Leaves.	Roots.	
Beet . .	59·86	154·39	15 to 20	
Carrot .	50·90	104·20		
Parsnip .	46·43	156·61		
Potatoes .	„	„	8 to 15	
Turnips .	„	„	5 to 8	
Clover hay	„	„	90 „	
Lucern .	25·80	„	„ „	
Meadow hay	„	„	50 to 100	
Rye grass	„	„	95	
Sainfoin .	16·71	„	„	
White clover	17·35	„	„	

Trees generally require less inorganic matter than grains and other crops, yet some trees, as the poplar for example, require as much mineral food as wheat, as may be seen by the following list of trees, 1000 parts in weight of which yield the quantity of ashes hereunder stated, namely,—

Ash . .	5 to 6	Fir wood . .	3¼
Beech .	1½ to 6	Oak . .	2
Birch . .	3½	Pine . .	1½ to 3
Elm . .	19	Poplar .	20
Fir bark .	17¾	Willow . .	4½
Fir leaves .	62¼		

If we now were to examine the constituents of the ashes left by the vegetables above enumerated, we should find that the proportion of the various ingredients of which these ashes consist vary likewise according to the species of vegetables.

The following table by Professor Johnston exemplifies this fact:—

	Wheat.	Barley.	Oats.	Rye.	Indian corn.	Beans.	Linseed.	Potato.	Turnip.
Potash . . .	237	136	262	220	325	336	245	557	419
Soda	91	81	...	116		106	234	18	51
Lime. . . .	28	26	60	49	14	58	147	20	136
Magnesia . . .	120	75	100	103	162	80	99	52	53
Oxyde of iron .	7	15	4	13	3	6	19	5	13
Phosphoric acid	500	390	438	495	449	380	381	125	76
Sulphuric acid .	3	1	105	9	28	10	9	136	136
Silica. . . .	12	273	27	4	14	12	57	42	79
Chlorine . . .	...	Trace	3	..	2	7	3	42	36
	998	997	999	1009	997	995	994	1007	999

The following table on the same subject has been compiled from various parts of Professor Liebig's "Chemistry of Agriculture:"—

	Fir leaves.	Fir wood.	Fir bark.	Hay.	Horse-Chetsnut, (fruit.)	Clover.	Sainfoin.	Beech wood.	Beech bark.	Pea straw, 1.	Pea straw, 2.	Potato straw.	Lucern.	Rye straw.	Wheat straw.		Grains of Wheat.	Bran of Wheat.
POTASH	...	...	...	...	51·0	...	...	...	...	...	...	...	...	...	...	12·5	15·0	14·
Carbonate of Potash ...	10·72	11·30	...	0·9	...	12·728	9·93	11·72	...	4·16	4·34	...	23 47	...	trace			
Carbonate of Soda		7·42	...	1·1	...	13·528	17·16	12·37	...	8·27		2·28	8 16		...			
Chloride of Sodium		trace	...	...	...	1·670	2·37	...	0 3·02	4·63	...	0 4·69	2·27	0·56	...			
Chloride of Potassium	...	...	2·95	1·3	3·0	...	...	...	0 ...	...	...	0 ...	...	0·25	3·2	3·0	0·16	0·16
Sulphate of Potash	1·95	trace		2·2		3·080	3·87	3·49	...	10·75	11·99	...	2·23	1·75	0·4	2·0		
Sulphate of Soda	...	...	...	1·2														
Silicate of Potash	3·90	...	...	...	...	...	...	...	...	...	...	...	...	16·09	13·0			
Phosphate of Potash ...	...	...	...	...	28·0													
Phosphate of Soda	...	...	...	...														
LIME	...	...	...	2 7														
MAGNESIA	...	5·60	0·93	8·6	...	4·160	9·11	7·74	16·90	4·05	3·76	3·76	6·41	1·92	9·6			
Carbonate of Lime	63·32	50·94	64·98	...	...	38·216	32·55	49·54	64·76	47·81	43·68	43·68	41·61	...	...	1·0		
Carbonate of Magnesia.	1·86	...	...	...	...	...	...	...	...	...	...	...	...	...	...			
Silicate of Lime	...	...	...	...	...	...	...	...	...	...	...	...	...	7·62				
Phosphate of Magnesia.	6·35	2·90	4·18	..	12·0	6·790	3·98	2·92	0·66	4·37	...	5·73	0·91	1·28	...	6·2	75·5	76·5
Phosphate of Lime......		3·43	5·03	16·1		11·970	15·37	3·32	2·71	5·15	5·73		11·80	2·50	2·3	5·0		
Phosphate of Manganese	...	trace	...	...	...	...	...	1·59	...	...	...	...	...	traces				
Basic perphosphate of Iron.........	0·88	1·04	1·04	5·0	...	1·240	0·64	0·76	0·46	0·90	...	1·30	...	3·20				
Basic phosphate of Alumina	0·71	1·75	2·42	...	...	...	...	1·51	0·84	1·20	2·75	2·75	...	...				
SILICA	10 31	13 37	17·28	60·6	0·5	5·438	2·79	2·46	9 04	7·81	15·54	29·81	2·26	63·89	71 5	61 5	0·5	0·5
LOSS	1·0	2·26	1·79	0·8	5·25	1·180	2·23	2·57	1·61	1·90	0·69	6·00	1·07	0·94	...	85·9	7·84	9·09
	100·00	100·00	100·00	100·0	100·0	1000·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Hertwig.			Haidlen.	Saussure.	Liebig.		Hertwig.						Fresenius.	Berthier.	Saussure.		

And not only do the ashes of plants vary in quantity and in kind, but equal quantities of ashes contain very unequal quantities of soluble and of insoluble matter; for whilst the ashes of certain plants are entirely soluble, others are only partially, and some scarcely at all soluble in water. The soluble portion of ashes consists entirely of *salts of potash and of soda*, the insoluble portion of ashes consists of *sand, of salts of lime*, and of *magnesia;* and according as these ingredients or salts predominate in plants, they are called *potash-plants, lime-plants*, and *silica* (sand) *plants.*

		Per cent.	
Potash-plants	contain more than	50	of soluble salts of potash or of soda.
Lime-plants	do.	50	of salts of lime, and of magnesia.
Silica-plants	do.	50	of sand.

The following table is taken from Liebig's "Chemistry, in its Application to Agriculture."

		Salts of Potash and Soda.	Salts of Lime and Magnesia.	Silica.
Silica-Plants.	Oatstraw with seeds (1)*	34·00	4.00	62.00
	Wheat-straw (2)	22·00	7·20	61·05
	Barley-straw with seeds (1)	19·00	25·70	55·03
	Rye-straw (3)	18·65	16·52	63·89
Lime-Plants.	Tobacco (Havannah), (4)	24·34	67·44	8·30
	„ (Dutch), (4)	23·07	62·23	15·25
	„ (grown in an artificial soil), (1)	29·00	59·00	12·00
	Pea-straw (4)	27·82	63·74	7·81
	Potato-herb (5)	4·20	59·40	36·40
	Meadow-clover (1)	39·20	56·00	4·90
Potash-Plants.	Maize-straw (2)	71·00	6·50	18·00
	Turnips	81·60	18·40	
	Beet root (6)	88·00	12·00	
	Potatoes (tubers), (6)	85·81	14·19	
	Helianthus tuberosus (7)	84·30	15·70	

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* In the above analysis, the figures represent the chemists as under:—

(1) Wiegmann and Polstorf.
(2) Saussure.
(3) Fresenius.
(4) Hertwig.
(5) Berthier and Braconnot.
(6) Hruschauer.
(7) Braconnot.

"This classification, however, is obviously only a very general one, and permits division into a great number of subordinate classes; particularly with respect to those plants in which the alkalies may be replaced by lime and magnesia. As far as we are authorised to judge by our present knowledge, a substitution of soda for potash takes places in our cultivated plants; but it has not yet been observed, that in these plants the alkalies can be replaced by lime."

"The potato plant belongs to the LIME-PLANTS, as far as regards the ingredients of its leaves, but its tubers (which contain only traces of lime,) belong to the class of POTASH-PLANTS. With reference to the siliceous plants, this difference of their parts is very marked."

"Barley must be viewed as a lime-plant, when compared with oats or with wheat, in reference to their ingredients soluble in muriatic acid; but it would be considered as a siliceous plant, if viewed only in reference to its amount of silica. Beet-root contains phosphate of magnesia, and only traces of lime; while the turnip contains phosphate of lime and only traces of magnesia."

It is, moreover, necessary for the farmer to bear in mind, as we already said before, that the quantity of ashes and the ingredients thereof vary, not only with every species of plant, but with the different portions of a same plant. This remark is of great importance, for whilst 1000 parts (in weight) of the ashes of the grains of wheat contain:—

28 of Lime,
120 of Magnesia, and
500 of Phosphoric Acid.

The same quantity of the straw of wheat contains:—

67 of Lime,
39 of Magnesia, and only
31 of Phosphoric Acid.

Consequently, a soil which contains enough phosphoric acid, lime, and magnesia to grow the straw of wheat, would be altogether incapable to grow, and would never produce the grain, or ear, as may be inferred from the table by Professor Johnston, which we quoted before.

CHAPTER IV.

OUTLINE OF THE PROPERTIES OF THE INGREDIENTS OF SOILS—CLAY—ITS QUANTITY IN GOOD ARABLE LAND—ITS INFLUENCE ON PLANTS—LIME-STONE OR CHALK—QUICK LIME—MARL—MAGNESIA—SAND OR SILICA—OXYDES OF IRON AND OF MANGANESE—SULPHUR—AMMONIA AND AMMONIACAL SALTS—COPPERAS—COMMON SALT—PHOSPHATES—SULPHATES—ORGANIC MATTER—USE AND ABUSE, APPLICATION AND EFFECTS OF THESE VARIOUS SUBSTANCES ON SOILS—SIMPLE TESTS BY WHICH THEIR PRESENCE MAY BE DETECTED.

Before entering into the details of the operations by which the nature or constitution of soils may be ascertained, we shall give a brief outline of the properties of the ingredients, the presence, and amount of which it is the object of the operator to detect.

CLAY.—*(Alumina.)*

If we take a piece of common alum, and having dissolved it in water, we add to the solution a certain quantity of ammonia (spirits of hartshorn,) or of a solution of common potash or soda, a white, bulky precipitate is produced, which is pure clay combined with water, and which chemists call ***hydrate of alumina.*** Clay is insoluble in water but it has a strong attraction for it, retains it accordingly with great energy, and, provided the quantity of water is not too considerable, it forms a stiff tenacious, and plastic paste, which can be moulded into any shape; clay may thus absorb and retain 70 per cent. of its weight of water. When diluted with much water, a great quantity of fine particles remain for a considerable time in suspension; the turbidness of rivers and other water-courses has no other cause. In the pure state, clay constitutes the ruby, sapphire, topaz, amethyst, and other hard gems.

Clay, or alumina, is one of the most widely diffused of all minerals on the surface of the earth. The soils called clayey and loamy, are combinations of this earth with various proportions of sand, lime, magnesia, and peroxyde of iron (rust), to which they mainly owe their colour, but in these soils clay predominates. Good arable land seldom contains more than from 30 to 35 per cent. of clay, and it is always present in fertile soils; yet clay (alumina) is seldom found in the ashes of plants, on the growth of which, however, it exercises an indirect influence, first by its power of absorbing the fertilizing agents contained in manures, and of dealing them out to the plants gradually as may be wanted (see *clayey soils*, page 5,) and also because it is always mixed with alkalies and alkaline earths in the disintegrated rocks which produce it, which alkalies and alkaline earths, we said, constitute part of the mineral food of plants.

LIME-STONE, OR CHALK.—*(Carbonate of Lime.)*

This earth, like clay, (*alumina,*) is one of the most abundant in nature; building, or free-stones, chalk, marble, oyster, and other shells, are all *carbonates of lime,* that is to say, a combination of *lime,* with a gas which is called *carbonic acid.* Carbonic acid is the gas which escapes when the cork of a bottle of soda-water, for example, is removed, and which renders the air of crowded rooms poisonous, because carbonic acid is unfit for the respiration of animals, and the air that we breathe out of our lungs contains carbonic acid. It is from lime-stone (carbonate of lime), that quick-lime is obtained; quick-lime is nothing else than carbonate of lime from which the gas called carbonic acid has been expelled by the action of the heat of the lime-kiln. Quick-lime is used to amend or ameliorate soils, because it effects the decomposition of some of their ingredients, and sets at liberty the alkalies, so essential to plants, which exist in clayey soils in a state of combination with the clay, and which would otherwise remain imprisoned in an almost insoluble state. Quick-lime is also exceedingly useful in soils which contain too much humus, because it expedites the decay of organic substances, and absorbs some of the gaseous products which are given off during the decomposing process; it combines, however, with the carbonic acid, which is always contained in the air, and soon returns to the state of carbonate of lime, or chalk. When quick-lime is intended for improving a soil it should be as fresh, that is as newly made, as possible, and if not immediately used, it should be kept in a dry, sheltered place, for the quick-lime might otherwise absorb one-fifth of its weight of water, which of course, would increase the expense of carriage, and it should be applied to the land in dry weather, for in damp weather it is liable to remain in lumps, which taking a longer time to absorb carbonic acid from the air, remain caustic, and may thus have an injurious effect on plants, as is the case when it contains caustic magnesia, (see *Magnesia*, page 29.) Quick-lime should always be in a pulverulent state before spreading it on soils.

From what has been said, it is clear that lime will be useful also in newly-cleared soils, containing a large quantity of undecayed leaves, roots, and rank grass.

Pure carbonate of lime, or chalk, being white, would be thus easily recognised, but as it is mixed in soils with coloured substances, it cannot be detected by that character. Nothing, however, is more easily ascertained than its presence, for it is sufficient to pour upon a small portion of the soil some diluted aqua-fortis, or muriatic acid, or even strong vinegar, if carbonate of lime be present a more or less violent bubbling and frothing will take place, as if the mass were boiling or simmering, which is due to the expulsion of the carbonic acid from the lime-stone (carbonate of lime). Carbonate of lime is insoluble in water, but if the water contains carbonic acid, it has then the power of dissolving carbonate of lime; and as common water, or rain always contains a certain amount of carbonic acid, a portion of carbonate of lime is thus dissolved, so that limestones or lime-rocks become disintegrated, both by the joint influence of abrasion and of solution. Carbonate of lime exists sometimes in soils in the state of calcareous sand.

MARL.

Marl, as we said before, is a mixture of clay and of chalk, which is more generally employed instead of lime for amending soils. *Marls* contain from 15 to 90 per cent. of chalk, and instead of clay they sometimes contain sand; hence the names of *clayey marls* and *sandy marls;* but to whatever class it may belong, it should crumble easily when left exposed to the air, for its action depends upon and is in proportion to its more or less divided state.

SAND.—*(Silica.)*

Sand is also one of the ingredients of almost all soils, which generally contain 85 or 90 per cent. of it. Under the name of sand must be included flint-stones, mill-stones, sandstones, grinding-stones, pebbles, agates, rock-crystal, quartz, sand being nothing else than these minerals in a state of disintegration. Pure silica or sand, is white, insoluble, and infusible, but if a certain quantity of potash or of soda be added, and the whole be exposed to a sufficient degree of heat, it fuses, and the result is *common glass;* and if the proportions of sand and of potash, for example, have been 70 of the first and 30 of the second, the glass resulting from their union is soluble in boiling water, and is known under the name of *soluble glass.* If the quantity of potash be less, so does the glass become less soluble, but no glass is perfectly insoluble, for when water is boiled in a glass vessel, a portion of the glass is always dissolved; neither is it requisite to apply heat to determine the action of potash upon sand, for although that action is of course greatly promoted by fusion, yet fine sand is always dissolved, to a certain extent, when in contact with an alkali. The combination of sand with an alkali such as potash, is called a *silicate of potash*, or *potash-glass*, which, being soluble, is then taken up by the roots of such plants to whose structure it is essential; it is thus that the cereales are provided with the glossy and hard coating, to which they owe the strength of their stalks, as we already said.

Silica, or sand is, moreover, mechanically useful in clay soils by diminishing their compactness, &c.—(See *Sandy Soils.*) It may be easily recognized by its grittiness. In soils, silica is generally combined with clay (*alumina*), and oxyde of iron, or with alumina, lime, magnesia, and oxyde of iron; and it is when soils contain more than 70 per cent. of sand that they are called *siliceous* or *sandy*.

MAGNESIA.

Magnesia is an earth which has some analogy with lime; it is found in nature in the state of carbonate of magnesia, generally mixed up with chalk (carbonate of lime), but in much less quantity than the latter. Like carbonate of lime, carbonate of magnesia may be rendered caustic or *quick* by the action of heat; that is to say, by roasting or burning it in a kiln, its carbonic acid may be driven off, and it is thus converted into *quick*, or *caustic magnesia*. Caustic, or *quick magnesia*, is much less caustic or strong than quick lime, but as it has less affinity for carbonic acid than quick lime, it does not absorb it so readily, and therefore remains caustic for a much longer time than the latter. Hence its action on soils may become baneful, and as it is often mixed naturally in certain lime-stones, which for that reason are called magnesian-lime-stones (*dolomite*), such lime-stones by burning become converted into a mixture of *quick lime* and *quick magnesia;* the former, as we said, soon returns to the state of carbonate of lime, but the latter remaining caustic for a much longer period, may prove hurtful or deadly to plants. When however, in course of time, it has become re-converted into carbonate of magnesia, it becomes inert.

Carbonate of magnesia is white, and resembles lime-stone; if an acid is poured upon it, it bubbles and froths up, just as is the case with carbonate of lime. In order to ascertain whether the lime-stone, which the operator may intend to convert into and use as quick lime, contains magnesia, he should pulverize a given weight, for example, 400 grains of the lime-stone, and dissolve them in diluted muriatic acid, taking care to use more acid than is required to dissolve the mass, and to stir the whole well in order to expedite and promote the solution. The lime-stone under examination being quite dissolved, ammonia (spirits of hartshorn) must be poured into the solution, stirring the whole, and adding more ammonia until the pungent smell of that liquid slightly predominates in the solution. This done, add a solution of oxalate of ammonia as long as a white precipitate is produced; throw the whole upon a paper filter—(see *Filtering*)—and collect the liquid, which percolates through the filter-paper, into a porcelain dish. The liquid which has filtered through contains the magnesia (if any) in solution, whilst all the lime is in the filter in the state of oxalate of lime. The operator should add a little more oxalate of ammonia to the liquid filtered from the lime, in order to make sure that all the lime has been separated; for if a white cloud or precipitate were then produced, it would be a proof that the liquid in question still retains lime, which must of course be separated by adding thereto an excess of oxalate of ammonia, and filtering. Admitting that all the lime has been got rid of in the manner mentioned, the filtered liquid should be evaporated to dryness, by placing the porcelain dish which contains it upon a sand or water-bath, so that the liquor may evaporate without spirting, to avoid which the mass should be constantly stirred towards the end. The saline residuum which is left in the porcelain dish should then be carefully transferred to a small crucible (for which purpose a platinum crucible is best), and kept therein for some time at a red heat; that is, until all fumes have ceased to be evolved from the residuum in the crucible. If a white sediment is left in the crucible, it is magnesia.

OXYDES OF IRON.

Peroxyde of iron is popularly known under the name of rust; it is that substance which generally imparts a red or reddish-brown, or a yellow colour to soils, which generally do not contain more than 3 or 4 per cent. of it, though in red-coloured soils this proportion is much more considerable. Peroxyde of iron is insoluble in water, and as it exists in almost every rock, it will of course be found in every soil.

It was just said that *rust* and peroxyde of iron were the name of the same substance, this, however, requires modification. If we take a piece of common green copperas (sulphate of iron), dissolve it in water, and then add thereto a solution of ordinary potash or soda, a dirty green or slatey precipitate will be produced, which is called protoxyde of iron. If a nail be placed into a tumbler, and aqua regia, or aqua fortis, poured upon it, and the whole be left at rest for some time, or heated, a portion of the nail, or all the nail, will be dissolved. If we now pour into that solution of the iron nail in aqua fortis an excess of a solution of common potash, that is, if we add the solution of potash until all effervescence or frothing up has ceased, a reddish brown precipitate will be produced, which is peroxyde of iron; both the green precipitate first produced, and the last reddish brown precipitate, are oxydes of iron, that is, combinations of the metal iron with a gas called oxygen; but whilst the first contains nearly 22¼ per cent. of oxygen, and is called protoxyde of iron; the second contains 30 per cent. of oxygen, and is called peroxyde of iron. Now *rust* is a mixture of these two oxydes of iron and of some carbonate of iron, that is, a combination of carbonic acid with the protoxyde of iron. When soils contain protoxyde of iron, they have a dark or black tinge, such is the case with certain clays, which are called *blue* clays—protoxyde of iron, exposed to the air, has a great tendency to pass into the state of peroxyde; the operator will, in fact, have observed, perhaps, after having poured the solution of potash into that of the green copperas as above-mentioned, that the surface of the dingy green precipitate produced assumed a brownish colour; this was due to the action of the oxygen of the air, which, striking upon the surface of the protoxyde of iron, converted it into a peroxyde, or *more oxydized compound* of iron. Organic substances, however, have, in certain cases, a contrary tendency, namely, that of converting the *peroxyde of iron* into protoxyde: this effect, when it takes place, has a baneful influence upon vegetation. The presence of protoxyde of iron is easily detected by boiling a portion of the soil in muriatic acid, filtering, pouring 40 or 50 drops of the solution into a wine glass, adding water, so that the glass may be half full, and then adding 1 or 2 drops of a solution of red prussiate of potash. If a dark blue precipitate is produced, protoxyde of iron was present. If no dark blue precipitate is produced, peroxyde of iron may be present, which is ascertained by testing again a portion of the solution with yellow prussiate of potash; if this produces an immediate dark blue precipitate, peroxyde of iron exists in the solution. Peroxyde of iron, however, may be contained in the soil, and yet not be dissolved by the muriatic acid employed; in that case a portion of the soil should be boiled in aqua regia, the mass is then diluted with water, filtered, and if, on pouring in the filtered liquor, either ammonia or a solution of potash, or of soda, a reddish brown precipitate is produced, it is peroxyde of iron; instead of ammonia, an infusion of nutgalls may be used, which will produce a purple black colour, which is ink; or else a solution of yellow prussiate of potash will produce a dark blue precipitate. Protoxyde of iron is converted into peroxyde of iron by aqua regia.

Oxyde of manganese is a dark brown powder, which is the oxyde of a metal called manganese, and which, like iron, has much affinity for oxygen. This oxyde is sometimes to be found in soils, but only in very small quantity, in the state of peroxyde, of carbonate, or of silicate; but as it has no action, or at any rate, as its action is not known, we need not otherwise take notice of it at present.

BRIMSTONE.

Brimstone (sulphur) is present in nearly all the parts of vegetables and of animals: mustard seeds and cress contain a large proportion of sulphur; it exists likewise in the white of eggs, the curd of milk, in hair and wool, &c. Sulphur is derived from compounds of that substance; when sulphur is burnt in the air, suffocating fumes are emitted, which are the result of the combustion of 1 part in weight of the sulphur employed with 2 parts in weight of the oxygen of the air, which have been necessary to burn it. This combination is called by chemists *sulphurous acid.* If a solution of sulphurous acid in water be kept for some time in an imperfectly stopped bottle, it will, after a few days, lose its suffocating odour, and become more acid; in fact, the sulphurous acid will have become converted into oil of vitriol (sulphuric acid) by absorbing 1 other equivalent or portion of oxygen. Sulphurous acid consists of 16 parts in weight of sulphur, and 16 parts in weight of oxygen; sulphuric acid (oil of vitriol) is 16 parts in weight of sulphur and 24 parts in weight of oxygen. Sulphuric acid contains therefore one-third more oxygen than sulphurous acid. Now oil of vitriol (sulphuric acid) forms by combining—

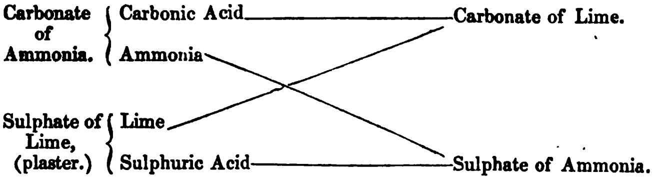
with potash,	sulphate of potash,
with soda,	sulphate of soda (Glauber's salt),
with lime,	sulphate of lime (plaster or gypsum),
with magnesia,	sulphate of magnesia (Epsom salts),
with alumina or clay,	sulphate of alumina (one of the constituents of alum),*
with oxyde of iron,	sulphate of iron (green vitriol or copperas).

* Alum is a double compound which consists of a combination of sulphate of alumina and of sulphate of potash.

It is from these and other compounds, of which sulphur forms part, that plants derive the latter ingredient, namely, sulphur. Sulphate of lime, plaster, or alabaster, gypsum, is the most abundant of these sulphates; in the native state it contains 20 per cent. of combined water, but is much less soluble in water than any of the above-mentioned sulphates, 430 parts in weight of water being required to dissolve 1 part of plaster. Although thus triflingly soluble, sulphate of lime exists in almost all springs and rivers, but more especially in the water of wells sunk in calcareous soils. Such water being incapable of cooking vegetables, and of dissolving soap, is called *hard water*, but it may be very easily and economically converted into *soft water*, and consequently rendered fit for all culinary and domestic purposes, by adding to it a small quantity of ordinary carbonate of soda, in the proportion of about half an ounce per gallon. The lime is thus precipitated in the state of carbonate of lime, which forms by settling, a white sediment, from which the soft water may be decanted or poured off.

Sulphate of lime or plaster being soluble to a certain extent in water, as we just said, may therefore be absorbed by such plants as clover, lucern, sainfoin, peas, beans, cabbage, rape, &c., for which it may be considered in the light of a special food. It is mainly the presence of plaster in solution which, as we just said, constitutes what is termed *hard water*, and in the same manner as such water is unfit for cooking, the vegetables boiled in it remaining hard and only partially *done*, so beans, peas, and cabbages, which may have been treated, whilst growing, with an excess of plaster, will more or less resist the action of boiling water. Some discrimination is therefore necessary on the part of the agriculturist in the use of that substance, and it should not be applied, except with care, to land on which such vegetables are grown for the table. On the other hand, it is evident that as plaster naturally exists in soils, sometimes to a considerable amount, the farmer should first ascertain whether it is present in his soil (if he wishes to grow such produce), and whether, therefore, a further addition might not prove useless as well as costly. Plaster has no effect on natural pasture lands, nor on the cereales, nor upon poor soils, on which the plants for which it is adapted are cultivated, even with such plants, the soil should be properly manured, or disappointment will follow.

Plaster (sulphate of lime, or gypsum) has another important action, namely, that of being decomposed by the carbonate of ammonia which exists in rain-water and in the air; it thus becomes converted into sulphate of ammonia, which being a fixed, that is, a non-volatile salt at the ordinary temperature, husbands up this important element, and prevents its waste. The reaction will be best understood by the following diagram.



When, therefore, soils do not contain naturally any sulphate of lime, the artificial addition of that substance may prove of the greatest value, 1st, as a special food to certain plants above named; and 2ndly, by fixing the ammonia of the air, and thus retaining it, subsequently to deal it out gradually to the plants in greater quantity than they otherwise could obtain it, at the same time leaving in the soil a proportion of carbonate or other salts of lime, which are the result of its decomposition.

The presence of sulphate of lime may be easily detected in water by the abundant white precipitate, which is produced when oxalate of ammonia or nitrate of baryta is added thereto.

SULPHATE OF IRON.—(*Green Copperas.*)

This salt is more a medicine than a food. A small quantity properly and judiciously applied, that is, applied where or when wanted, may invigorate plants under peculiar circumstances; but, like most medicines, if administered in too large doses, or in unsuitable cases, it may prove injurious or mortal. It is useful in what may be called the jaundice of plants. A very dilute solution of green copperas restores their green colour and vigour. It is therefore a *tonic*, but a slight overdose may kill. Soils which naturally contain sulphate of iron, as is the case in some pyritous lands, are always more or less barren.

The presence of soluble sulphates in soils is very easily ascertained as follows:—Take a certain quantity of the soil, say about four ounces, crumble it between the fingers into coarse powder, and put this into a dish, saucepan, or flask, and pour upon it about ten ounces of pure *distilled water*, boil the whole for a few minutes, and throw the mass upon a paper filter. Add a little nitric acid to a portion of the filtered liquor, and if the further addition of a few drops of a solution of nitrate of baryta produces a white precipitate insoluble in water and in acids, it indicates that a soluble sulphate is present in the soil. The presence of iron in the filtrate is recognized exactly in the manner described, p. 32.

COMMON SALT, OR MURIATE OF SODA.—(*Chloride of Sodium.*)

Common salt is a compound consisting of a gaseous substance called chlorine, and of a metal, sodium; in the same manner as soda is called oxyde of sodium, that is, a combination of oxygen with sodium, so the combination of chlorine with that metal is called chloride of sodium. Chlorine is the gas which is employed for bleaching and disinfecting; it is a highly suffocating and poisonous gas.

Common salt exists in all soils, and in almost all waters. Its application to marley and clayey soils appears to be attended with good results, as affording a supply of soda instead of potash, which, being necessary to the development and growth of vegetables, is often found deficient in quantity. "A small proportion of common salt," says Professor Johnston, "is absolutely necessary to the healthy growth of all our cultivated crops." But a larger proportion is injurious, wherefore the operator should take into consideration the quantity of this, or of other soluble chlorides which may already be contained in the soil, and likewise in the manures used.

The detection of the presence of common salt and of other soluble chlorides in soils is extremely easy. To another portion of the liquor filtered from the four ounces of earth, treated by distilled water as mentioned in page 36, add solution of nitrate of silver. If a white curdy precipitate, or cloudiness is produced, which immediately disappears by the addition of amomnia, the presence of common salt, or of any other soluble chloride, is certain. By exposure to light the above mentioned curdy precipitate turns black.

PHOSPHATES.

Phosphorus is a soft substance of a waxy appearance, and of a pale yellow colour, shining in the dark, which effect is due to a slow and quiet combustion of the phosphorus by the oxygen of the air, wherefore phosphorus is always kept in bottles full of water; it has an odour of garlic. If phosphorus be rubbed upon a rough surface, or touched with a heated substance, or incautiously handled with warm hands, it immediately burns with violence and with an exceedingly bright and dazzling white flame, a thick white cloud being at the same time produced which consists of phosphoric acid; that is, a combination of phosphorus with the oxygen of the air Now the bones of animals consist chiefly of a combination of this acid with lime, called phosphate of lime, of glue, and of fat. When bones are put into the fire, the glue and the fat burn away, and they become converted into a white sort of earth, called calcined bones, or *bone-ashes*. These *bone-ashes* consist almost entirely of phosphate of lime, which is also present in the ashes of plants. Grains, roots, flesh, and all the usual articles of food contain a certain proportion of phosphoric acid, and it is worthy of remark that the most nutritious alimentary substances contain the greatest proportion of this acid in a state of combination, generally with lime or magnesia, that is to say, in the state of phosphate of lime and of phosphate of magnesia. Wheat, for example, contains a large quantity of both phosphates of lime and of magnesia; and Professor Liebig says that alkaline and earthy phosphates form invariable constituents of the seeds of all kinds of grains, of beans, peas, lentils, &c., earthy phosphates exist also in beer, sometimes to the amount, according to M. Johnston, of 50 or 60 grains per gallon; their presence in this beverage is derived from the barley, or malt used in its manufacture. Phosphoric acid, in a state of combination with alkalies and with earths, is such an important ingredient of soils, that plants cannot ripen in soils in which these phosphates are wanting; hence, the beneficial effects of bone dust as manure. According to Theodore de Saussure, the ashes of wheat contain no less than 44½ per cent. of phosphates of lime and of magnesia. The presence of phosphoric acid cannot be summarily detected, we must therefore refer the reader to the chapter on the analysis of soils, where the necessary instructions are given for the detection of phosphoric acid, and also of potash and of soda.

AMMONIA.

If the substance called sal-ammoniac be rubbed in a mortar or mixed with quick-lime, or with potash, or soda, a gas which has a very pungent odour is evolved, which is ammonia.

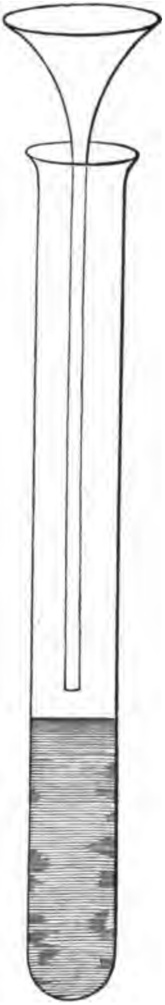
This gas is very soluble in water, and the solution of ammonia in water constitutes the spirit of hartshorn. Ammonia has also a great affinity for carbonic acid, with which it forms a salt, called carbonate of ammonia, otherwise known under the popular name of *smelling salts*. Ammonia is a compound resulting from two gases, named nitrogen and hydrogen, and it is from this source principally that plants derive nitrogen, a small quantity of which is always found in their structure or juices, and which is necessary to, or probably determines the conversion of the soluble substances contained in the saps into insoluble fibres. Ammonia is always produced when vegetable, but more especially animal matters are left to decay; the ammonia so produced is evolved in the air, where it soon enters into combination with carbonic acid, to form carbonate of ammonia, which being a volatile salt, extremely soluble, like ammonia itself, in water, is taken up by rains and by them conveyed to the soil, into which it sinks, and is subsequently taken up by the roots of plants. "It is worthy of observation," says Liebig, "that the ammonia contained in rain and in snow water, possesses an offensive smell of perspiration, and of putrifying matter,—a fact which leaves no doubt respecting its origin." The same author observes: "In the manufactories of beet-root sugar many thousand cubic feet of juice are daily purified with lime, in order to free it from vegetable albumen and gluten, and it is afterwards evaporated for crystallization. Every person who has entered such a manufactory must have been astonished at the great quantity of ammonia volatilized along with the steam. This ammonia must be contained in the form of an ammoniacal salt, because the neutral juice possesses the same characters as the solution of such a salt in water; it acquires namely, an acid reaction during evaporation, in consequence of the neutral salt being converted, by loss of ammonia, into an acid salt. The free acid thus formed is a source of loss to the manufacturers of sugar from beet-root, by changing a part of the sugar into uncrystallizable grape sugar and syrup.

"The products of the distillation of flowers, herbs, and roots, with water, and all extracts of plants made for medicinal purposes, contain ammonia. The unripe, transparent, and gelatinous pulp of the almond and peach emit much ammonia when treated with alkalies. (Robiquet.) The juice of the fresh tobacco leaf contains ammonical salts. The water which exudes from a cut vine, when evaporated with a few drops of muriatic acid, also yields a gummy deliquescent mass, which evolves much ammonia on the addition of lime. Ammonia exists in every part of plants, in the roots (as in beet-root), in the stem (of the maple-tree), and in all blossoms and fruit in an unripe condition.

"The juices of the maple and birch contain both sugar and ammonia, and therefore afford all the conditions necessary for the formation of the azotised components of the branches, blossoms, and leaves, as well as of those which contain no nitrogen. In proportion as the development of those parts advances, the ammonia diminishes in quantity, and when they are fully formed, the tree yields no more juice.

"The employment of annimal manure in the cultivation of grain, and the vegetables which serve for fodder to cattle, is the most convincing proof that the nitrogen of vegetables is derived from ammonia. The quantity of gluten in wheat, rye, and barley, is very variable; these kinds of grain also, even when ripe, contain this compound of nitrogen in very different proportions. Proust found French wheat to contain 12·5 per cent. of gluten; Vogel found that the Bavarian contained 24 per cent.; Davy obtained 19 per cent. from winter, and 24 from summer wheat; from Sicilian 21, and from Barbary wheat, 19 per cent. The meal of Alsace wheat contains, according to Boussingault, 17·3 per cent. of gluten; that of wheat grown in the "Jardin des Plantes," 26·7; and that of winter wheat, 33·3 per cent. Such great differences must be owing to some cause, and this we find in the different methods of cultivation. An increase of animal manure gives rise not only to an increase in the number of seeds, but also to a most remarkable difference in the proportion of the substances containing nitrogen, such as the gluten."

The presence of ammoniacal salts in soils is easily detected; it is sufficient to treat a portion of the soil with a certain quantity of pure distilled water, and to filter. A little muriatic or sulphuric acid is then added to the filtered liquid, it should then be concentrated by boiling, and the concentrated solutions should then be introduced into a glass tube. A small quantity of a solution of soda is poured into it by means of a glass-tube funnel, in order to avoid wetting the sides of the tube. The whole is then heated, and if by holding a strip of slightly reddened litmus paper at the tube, the strips of paper become blue, ammonia is present, and may often be recognized by its odour if it exists in any quantity, but a trace which could not be recognized by the odour is immediately detected by the blue tinge which the test paper acquires.



ORGANIC MATTER, HUMUS.

The organic matter existing in soils is generally partially soluble, and partially insoluble, but in either case it always consists of the detritus of vegetables, which sometimes exist in such abundance that the soil scarcely contains any thing else, as for example, in peaty soils. The woody portion of decaying vegetables is called *humus*, and is the principal source from which plants derive their carbon, not in a direct manner (for humus, in the state in which it exists in the soil, cannot be absorbed by plants), but as will be explained presently. All plants, besides the earths and saline substances of which we have been speaking, consist of three gases, namely, *oxygen*, *hydrogen*, and *nitrogen*, and one solid substance, which is *carbon* or charcoal. The diamond is nothing else but pure carbon, and charcoal is an impure diamond, which differs from the precious gem only by a small amount of impurities (the ashes left after burning it), and by its form. When wood is burnt out of the contact of the air, for example, in a crucible filled with sand, or in heaps covered with turf or clay, charcoal or carbon remains, which in edible or alimentary vegetables, previously dried, forms about 50 per cent. of the whole weight. If, now, the charcoal so produced be burnt in the open air, it disappears in the form of a gas called *carbonic acid*, and nothing remains but a small quantity of ashes which were the impurities, or inorganic portions contained in the charcoal. The carbonic acid produced was therefore the result of the combustion of the charcoal or carbon by the oxygen of the air, and each 6 lbs. of carbon, thus combined with 16 lbs. of oxygen, forms 22 lbs. of carbonic acid. Now carbonic acid is the carbon-containing compound from which plants derive their carbon, that is, about one half, or 50 per cent. of their weight, which they absorb from the air by their roots and by their leaves. The formation of carbonic acid gas is always the result of a combustion, which sometimes is energetic, as when wood or charcoal is set on fire, but which sometimes also is slow, and not less complete, though unseen, as is the case with the dead vegetable detritus or humus in the soil, which, under the influence of the air, is gradually and slowly burnt, and the charcoal of which becomes insensibly converted into carbonic acid. As the decay of these vegetable remains advances, however, the humus becomes converted into various organic acids, it gradually loses this property of producing carbonic acid, until at last nothing remains but a black insoluble substance (ulmine and humine) in which this property is altogether wanting.

Although the presence of humus is a condition of fertility in soils, yet it may exist in them to such an excess as to become hurtful; this is the case with peaty soils. Oats and rye will grow upon a soil containing only 1½ per cent., barley when 2 to 3 per cent. of organic matter are present, while good wheat soils generally contain from 4 to 8 per cent.; in stiff and clayey soils from 10 to 12 per cent. of humus is sometimes found. Another influence of this organic portion of the soil, whether naturally formed in it, or artificially added to it as manure, is not to be neglected. We allude to its containing, as all vegetable substances do, a considerable quantity of inorganic, that is, of saline and earthy matter, which is liberated as the organic part decays. Thus living plants derive from the remains of former races, buried beneath the surface, a portion of that inorganic food which otherwise can only be obtained from the soil, and which, if not thus directly supplied, must be sought for by the slow extension of their roots through a greater depth and breadth of the earth in which they grow.—*Johnston.*

The presence of organic substances in soils is most easily ascertained as follows: take a handful of the soil, put it into a crucible, and expose it therein to a red heat, taking care to stir it with an iron rod whilst at a red heat; it will at first become black, which will be due to the charring of the organic matter, and if animal matter is present, an odour of ammonia will be evolved.

CHAPTER V.

SIMPLE METHODS BY WHICH THE RELATIVE PROPORTIONS OF THE CHIEF INGREDIENTS OF SOILS MAY BE ASCERTAINED—HOW TO DETERMINE THE PROPORTIONS OF MOISTURE, OF CLAY, OF LIME, OF HUMUS AND OF SAND, CONTAINED IN SOILS—DETERMINATION OF THE SPECIFIC GRAVITY OF SOILS, THEIR CAPILLARITY AND POWER OF ABSORBING AND RETAINING WATER.

HAVING enumerated in the preceding chapters the substances which must exist or be introduced into soils as necessary ingredients of the structure of plants, and having indicated the properties of these various substances, I shall now endeavour to point out how their presence can be recognized and their amount appreciated. The series of experiments which lead to the detection and identification of the substances contained in a soil, is called the "qualitative analysis" of that soil, and the experiments by which the operator ascertains to what amount these substances exist in a soil, that is to say, their quantity, is called *quantitative analysis.*

When one of these substances predominates much in a soil, it may generally be recognized at once, and almost at a glance. For example, the white colour of the soil indicates an abundance of chalk or of gypsum; a reddish, or brown colour, that of peroxyde of iron; a dark or black colour, that of humus, &c.; but these characteristics, although capable of indicating to an experienced person the general nature and capabilities of soils, are insufficient to give the agriculturist the necessary information respecting their intimate constitution, their density, their power of absorbing and of retaining water and heat, the knowledge of which properties can alone guide him in the best way of managing, manuring, and improving his soils, nor can he otherwise acquire or form a correct estimate of their probable fertility, nor of their respective value for sale or purchase.

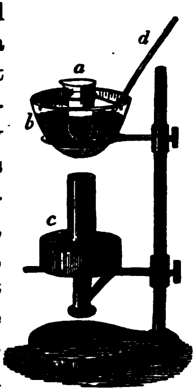
The principal constituents of a soil, the amount of which it is particularly important to determine, are those which have been enumerated in Chap. II., and on which Schübler's classification of soils is grounded; I mean clay, lime, humus, and sand. For certain ordinary purposes, such as for example, when the object in view is simply to determine approximatively the proportion of clay and of sand contained in a soil, a simple mechanical analysis may suffice, which may be done as follows:

FIRST OPERATION.

If the soil which it is intended to examine have a different appearance at various parts of the field, it is absolutely necessary to take as many samples as may be judged requisite, giving a number to each, and keeping them separate. In this case the operator should at the same time draw upon a piece of paper a sort of sketch of the ground, and divide and mark it with numbers corresponding to that of the samples which have been taken, and the results of the analysis of each sample are subsequently written on the sketch itself, on the part marked with the number corresponding with the sample.

If the constitution of the soil appears uniform, it will be sufficient to take a sample at various parts of the ground, and at about three inches from the surface. These samples may then be mixed up together, so as to form an average sample. All samples should be kept in air-tight bottles.

These preliminaries being attended to, take half a pound of the sample, expose it freely to the air upon a sheet of paper in a dry room, until on re-weighing it after four or five hours' exposure, it no longer diminishes in weight. The loss of weight is due to a loss of water which has evaporated. This loss of weight, however, is far from indicating the proportion of all the water contained in the soil, for a considerable quantity is still retained with an energy proportionate to the amount of clay and of or ganicmatter present; it is therefore necessary to apply a certain degree of heat sufficient to expel the water which is thus retained, yet not high enough to decompose the organic matter. This may be done as follows: triturate gently in a mortar the air-dried soil above alluded to, in order to reduce whatever earthy lumps there may be into coarse powder, and remove all the small stones, either by the hand, or better still by means of a sieve, which separates at the same time a certain portion of undecayed organic detritus. Of this sifted soil take 500 grains, and expose them in a small counterpoised glass-beaker to a heat of between 280° and 300° Fahr. in an oil-bath, as represented in the fig., until they no longer diminish in weight, which is ascertained by withdrawing the small glass-beaker from the oil-bath from time to time, carefully wiping it and then weighing it, until two successive weighings, at about half an hour's interval from each other, are found to be the same; the loss finally observed indicates, of course, the proportion of water. In the above fig., *a* is a small glass-beaker containing the air-dried soil; *b* is the oil-bath, *c* is the argand oil-lamp, *d* is a thermometer.



SECOND OPERATION.

This being done, put the above exsiccated soil into a Phillips' precipitating glass; pour about four or five ounces of boiling water upon it, in order to dissolve the soluble substances; and having boiled the whole for about a quarter of an hour, leave at rest for a few moments. The sand, being heavier, falls down, whilst the clay remains in suspension in

the water, which must be carefully poured off into a large glass-beaker; more water is then added to the sandy residuum; the whole is stirred, left at rest for a few moments again, another portion of clay remains suspended in the water, which must be carefully poured off into the large glass-beaker containing the first portion of water holding the clay. This operation is repeated again and again, until the water shaken or stirred up with the sandy deposit becomes clear after a few moments' rest. The water containing the clay is left undisturbed until it is quite settled, and it is then thrown upon a paper filter. The water having completely drained from the clay retained by the filter, the latter is carefully opened and spread out upon a brick, a cake of dry plaster, or some such absorbant substance, in order to dry the clay which should afterwards be transferred to a glass-beaker, and dried in the oil-bath at about 300° Fahrenheit, as above said, until it no longer loses weight, after which it is weighed.

THIRD OPERATION.

The sand which was left in the beaker separate from the clay should be treated exactly in the same manner, and thus the respective quantities of clay and sand contained in the soil become approximatively known. And as the insoluble portion of humus is present in the clay and sand, its amount may at once be easily determined by putting both the clay and the sand obtained, as just said, into a crucible, keeping them at a red heat, and stirring the mass with an iron rod, until the organic matter is destroyed, which is known when all the particles of charcoal, resulting from the charring of the organic matter, have disappeared. On weighing the mass again, the difference or loss of weight of course indicates the proportion of humus. This experiment, however, is very far from being accurate, for it reckons as clay and sand that which may be a mixture of clay and chalk, or of sand and chalk, and it is only when the object of the operator is simply to have some idea of the respective proportions of sand and of clay mixed with chalk that the process described can be available. The following method is more to the purpose, and by it the operator may be enabled at once to ascertain to what class of soils that on which he has experimented belongs, according to Schübler's table given, page 14. Take half a pound of the soil to be examined, and dry it as was described pages 45, 46. Take 500 grains of this exsiccated soil, and expose it in a crucible, to a red heat, stirring all the while, until all the organic matter is burnt away; this being done, and the mass having cooled, it is weighed, the loss sustained is taken account of as humus.

FOURTH OPERATION.

In order now to determine the presence and proportion of lime, or rather of chalk (carbonate of lime) proceed as follows:—The mass which was ignited, that is, heated to redness in a crucible, and weighed as just said, should be transferred to a porcelain capsule, and dilute muriatic acid, that is, muriatic acid to which seven or eight times its weight of water has been added, is then poured upon it. If a bubbling or frothing is produced, the presence of a carbonate (which is most probably carbonate of lime) is proved, a gentle heat is applied until all effervescence has completely ceased. A small quantity of diluted muriatic acid is added; if this produces again an effervescence, it is a proof that there was not enough muriatic acid employed in the first instance, and that the mass contains still some undecomposed carbonate of lime, more muriatic must therefore be added, in fact until it ceases to produce an effervescence. When this point is attained, the whole is thrown upon a fresh paper filter, and water is poured upon the mass in that filter gradually as it filters through, until the filtrate has no longer any acid taste. The filter containing the mass is then carefully spread flat upon an absorbing brick or cake, and when its contents have become dry they are transferred to a small glass-beaker, exposed therein to a heat of about 300° Fahr. in an oil-bath as above said, and dried, the difference of weight or loss is noted as lime or carbonate of lime.

This dry residuum, from which the lime has been removed, may now be treated by levigation (as described page 46, in order to separate the clay and sand), and by looking at the different results obtained, namely:—

1. The loss sustained from exposure to a red heat, indicating the proportion of . . . . . . Humus,
2. The loss sustained from the treatment with muriatic acid, indicating . . . . . . Lime,
3. The weight resulting from the levigation, and separation of the lighter portions of soil which were held in suspension in the water, indicating . . . Clay,
4. The weight of the portion of soil which sank during the levigation, indicating . . . . . Sand,

it is very easy to refer the soil to its proper place in the table. Let us suppose, for example, that the 500 grains of air-dried soil,

1.	have lost of humus by ignition .	10 grains.
2.	do. of lime by muriatic acid .	15½ „
3.	have left of clay	131¼ „
4.	do. of sand	353¼ „
		500

Each of these numbers divided by 5, since the operation was performed upon 500 grains, will give 2 per cent. of sand, $3\frac{1}{10}$ per cent. of lime, 26¼ per cent. of clay, and the rest, or $70\frac{65}{100}$ per cent. of sand, which proportions constitute the 3rd class of sandy loams, in Schübler's table, that is, a rich calcareous sandy loam.

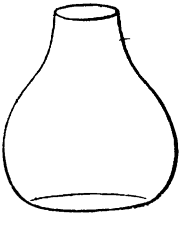
The specific gravity of soils may also indicate to a certain extent their constitution, and if we were in possession of a sufficient number of experiments on the specific gravities of different soils of known composition, systematically arranged in a tabular form, we might perhaps, in many instances, simply by taking the specific gravity of any given soil, dispense with the necessity of making a chemical analysis in order to ascertain its constituents. The term specific gravity means the relative weight of a body of a certain volume, compared to that of another body of a same volume taken as a standard. The specific gravity of a body expresses therefore, the proportion or quantity of matter contained in a body, compared to the proportion or quantity of matter contained in another body of the same bulk. The specific gravity of solid and of liquid bodies is compared with that of pure distilled water, at 60° Fahrenheit. One cubic foot of such water weighs very nearly 1000 ounces, and its gravity being taken as the unit or point of comparison, is marked thus :—1·000. When therefore, we find the specific gravity, of mercury for example, represented by 13·58, it means that mercury is 13 and $\frac{58}{100}$ times heavier than water, or, in other words, that whilst one cubic foot of pure distilled water weighs 1000 ounces, one cubic foot of mercury weighs 1358 ounces.

The specific gravity of a soil may be taken by means of a specific gravity bottle, adjusted so as to contain exactly 1000 grains of water. It is evident that if such a bottle were filled, instead of pure water, with a substance the specific gravity of which is twice, thrice, four times that of water, the weight of a bottle full of it would accordingly be 2000 grains, 3000 grains, 4000 grains, &c., and the specific gravity of such substances would be expressed as follows: —2·000, 3·000, 4·000. A bottle containing 1000 grains, however, is generally too large, wherefore one adjusted to contain 500 grains of water is preferred. The process for taking the specific gravity of a soil with such a bottle, consists in weighing accurately into it 375 grains of water, then gradually adding the soil, previously air dried, to such a height that, on replacing the stopper, the bottle is found to be quite full without either overflowing, nor yet leaving any air between the stopper and the surface of the water, and then weighing the whole. Now, it is clear that the bottle having a capacity of 500 grains, and having been filled in the first instance with only 375 grains, a space was left which would have admitted 125 grains more of water; suppose that after having added a sufficient quantity of soil to fill that space completely, andwe ighing the bottle, it is found

To weigh	625	grains.
Deduct the weight of the water first employed	375	„
The remainder is	250	

These 250 grains represent therefore the weight of the bulk or quantity of soil which has been required to fill up the bottle completely, and as the weight of the bulk of water necessary to do this would have been only 125 $(375+125=500)$, it follows that by dividing the weight of the soil added, namely 250 grains, by that of the soil which would have occupied the same bulk or space, namely 125, we obtain 2· as the specific gravity of the soil, which is thus found to have double the specific gravity of water; in effect, twice 125 is 250.

Another form of specific gravity-bottle, is that contrived by Mr. Rham; it is perhaps the most convenient for the purpose, and is represented in the figure. This bottle contains about 500 grains of water, more or less; it has no stopper, and the neck is ground perfectly flat. It is used as follows:—Fill the bottle with pure distilled water at 60° Fahr., so that the surface of the water be even or level with the edges or rim of the neck of the phial. If the level of the water, instead of being



perfectly flat, is convex, it is a sign that too much water has been poured into it; in the contrary case, there will be a depression, that is to say, the surface will be concave; and as it is important that the surface should be perfectly flat, the operator may obtain the desideratum in the first case by touching the convex liquid with a piece of blotting-paper, which, by absorbing the liquid, will reduce the level; in the contrary case, a small drop or two of water may be easily added by means of a pipette. Supposing, therefore, that the water in the phial is properly adjusted, as just said, without forming any depression or convexity, the whole must be accurately weighed. This being done, put in the scale which contains the phial filled with water a 100 grains-weight, and by means of a pipette suck water out of the phial until the equilibrium is restored, which will be of course when a quantity of water, exactly corresponding to the 100 grains-weight added to the scale, will have been sucked out. Make now a counterpoise of lead for the whole, which counterpoise will serve for all future experiments. The bottle being prepared as described, the specific gravity of soils is taken in the following manner:—

Fill the phial partially with water, and place it on one side of the scales, put the counterpoise on the other side of the scales, and add water to the phial, or take some from it, until the equilibrium is restored. This done, small portions of the soil to be tried are carefully and gradually dropped into the phial until the water therein rises to the top so as to be perfectly level with the rim; and when this result is attained, grain-weights are added in the other scale until the equilibrium is again restored. The number of these grains indicate the specific gravity of the soil.

According to Schübler the specific gravity of the following earths is:—

Calcareous sand	2·822
Silicious sand	2·753

Clay *	2·701
Stiff clay †	2·652
Argilaceous soil ‡	2·603
Blue clay ‖	2·591
Fine calcareous earth	2·468
Gypsum or plaster	2·358
Sandy clay	2·335
Garden soil §	2·332
Stiff clay (fair wheat soil)	2·276
Sandy loam	2·150
Humus	1·225

This table shows that those soils which contain most *sand* are the heaviest, and consequently that in proportion as the quantity of sand diminishes in *clay soils*, so does their specific gravity, and that a low specific gravity generally indicates a larger proportion of humus or of organic matter.

The *capillary affinity* of soils, their *permeability*, their *power of absorbing*, and of *retaining water*, are also properties which it is of the utmost importance to determine, since their fertility in a great measure depends upon, or, at any rate, is greatly influenced by these properties. Before entering into a detail of the methods by which these points can be ascertained and estimated, a few explanatory words may not be unacceptable to the unlearned.

If, taking a glass tube open at both ends, we plunge one of its extremities into a basin of water, we may observe that the water of the basin will immediately and of itself ascend into

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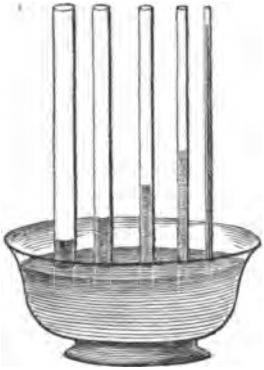
[*] This soil on an average contains 40 per cent. of fine silicious sand, which may be separated by agitation in water and subsidence, as we described.

[†] This soil contains 24 per cent. on the average of fine silicious sand, which may be separated in the same manner.

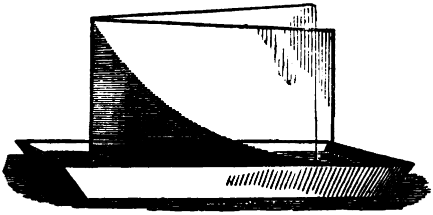
[‡] 10·75 per cent. of fine silicious sand may be separated from this soil.

[§] Contains no free sand of a bluish-grey colour, composition silica 58, alumina 36·2, oxyde of iron 5·2.

[‖] Composition clay 52·4, silicious sand 36·5, calcareous sand 1·8, chalk 2·0, humus 7·2.



the tube to a height proportionate to the size of the bore of the tube, and which, in those of a very small bore, is surprisingly considerable, as represented in the adjoining fig.; or if two window panes of glass be placed in a dish of water so that they touch it only by their lower extremities, and if the two panes of glass be then brought in contact together by their vertical edges on one side only, the water in the dish will be observed to ascend in a curved line, the liquid rising highest at the sides where the plates of glass are nearest each other. Now these effects are due to capillary affinity, that is to say, to the affinity of the liquid for the glass which it wets, and to the attraction of the molecules of the liquid for each other. The effect does not depend in any way upon any peculiar property of the glass, or of the water, since it invariably takes place with all substances, and with all liquids, without exception whatever, the only necessary condition being that the one may be wetted by the other. Neither has the form of the substance anything whatever to do with the phenomenon. Thus, every body knows that if a lump of sugar, for example, be put in contact by one of its extremities with coffee, or with tea, the liquid will ascend into and pervade the whole mass of the sugar. Again, everybody has made the



unpleasant observation that if a drop of oil falls upon a garment, it will produce a stain which will go on extending and enlarging to an exceedingly unsightly size; the sponge which sucks the water in, the wick of a lamp which becomes permeated with oil, a clot of earth which becomes damp through by contact with a few drops of water, are all familiar examples of capillary attraction and permeability.

Considering that it is on account of these two properties that soils may become uniformly permeated with moisture, and that the salts contained in the soil, and which have been dissolved by that moisture, are enabled to ascend into the roots of vegetables, the knowledge of the amount of these properties, that is to say, the degree of facility with which water may pass through a given soil, and of the amount of that water which is retained by it after absorption, is of great practical importance, and may be obtained in the following manner:—

Take one pound weight of each of the soils to be examined, using the same precautions as before mentioned, in order to secure a good average sample of each, and expose these samples in a steam bath to a temperature of 212° Fahrenheit. Sift, rub in a mortar, and again expose to 212°, until it is observed that the sample is no longer losing weight. Pour now successively on each sample a pint of water, stir the mass well, and throw it upon a silk or hair sieve supported over a basin. Pour then again over it, and with care, in order not to disturb the level of the soil in the sieve, another pint of water, and note the time that will be required by the water to filter through. Between pure sand which allows the water to pass through as fast as it is poured on it, and pure clay which scarcely allows of any water to pass through at all, a comparative estimate of the permeability of the soil is easily attained.

The retentive power of the soil is ascertained in quite as simple a manner: take 500 grains of the soil, dried at 212° as before-mentioned; put them into a glass-beaker, and pour upon them about half a pint of water; prepare a filter of suitable dimensions, wet it with water, and then pour into it the soil, mixed with water as just said; rince the beaker with water in order to wash it clean, and, of course, pour the rincings into the paper-filter. When it is observed that the water, which was put into the filter with the soil, has completely filtered through, the soil must be gathered up and removed from the filter, and weighed, with its contents, in the moist state. The increase of weight, of course, is proportionate to the quantity of water absorbed and retained by the soil.

The following table shows the results obtained by this mode of operating with various soils:—

Soils.	100 parts retain—
Siliceous sand	25 of water.
Gypsum (plaster of Paris) . .	27 do.
Calcareous sand	29 do.
Clay	40 do.
Stiff clay	50 do.
Clayey soil	60 do.
Fine calcareous earth	85 do.
Garden soil	89 do.
Humus	190 do.

This table shows:—

That siliceous sand retains less water than any other soil;—

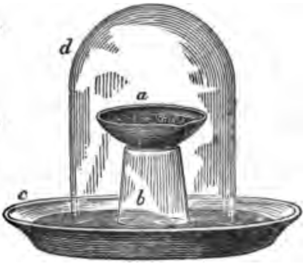
That the retentive power of clayey soils is so much the greater, as they contain less sand;—

That calcareous sand and calcareous earth, though both consisting of chalk, are very different in their absorbing and retentive power. Hence the necessity, in examinations of this nature, to pay attention to the form of this constituent of soils, for a chemical analysis would not be here of the slightest assistance, or possibly might even mislead the operator.

POWER OF ABSORBING MOISTURE FROM THE AIR.

Another very important property closely connected with the fertility of soils, is their power to absord water or moisture from the air. During the night, the soils which possess this property in a sufficient degree are enabled to condense a suitable quantity of water, and to make up in that way for the evaporation which takes place during the day, which evaporation, in dry seasons, is enormous; the plants on such soils are thus supplied with moisture and thrive, whilst on those in which this absorbing power is insufficient or deficient, the plants are parched, burnt up, and die.

One of the most convenient methods of determining the amount of water-absorbing power in soils, consists in taking a given weight, for example 1000 grains of the soil well dried, as mentioned page 45, and exposing it upon a support in a counterpoised shallow capsule, of either platinum or porcelain, placed in a large dish containing about half an inch of water. A large glass bell or jar is then put over the capsule and the support, in such a way that its mouth dips into the water of the dish on which it rests, as here shown:—



a is a counterpoised capsule containing 1000 grains of perfectly dried soil.

b is the capsule support, which, for convenience sake, may be a beaker or a glass-tumbler.

c is a dish containing a sufficient quantity of water to close up the mouth of the glass jar *d*.

d a glass jar, with its mouth immersed into the water of the dish *c*, containing the dried soil in the capsule on the support.

The soil having been left under the jar as just described for a given time, which should not be less than twelve hours, the temperature of the apartment being kept uniform during the time, the operator should remove the capsule and weigh it immediately, so that no loss may be sustained by evaporation, and the increase of weight over and above the 1000 grains of the experiment indicates, of course, the quantity of water absorbed by the sample, and consequently, the absorbing power of the soil from which it was obtained. Generally speaking, 1000 grains of good soil should thus absorb from about sixteen to twenty-one grains of moisture.

The following Table from Schübler (see Journal of the English Agricultural Society, Vol. VI, page 196) gives the results obtained by the above mentioned method.

Kinds of Earth.	1000 grains spread on a surface of 50 square inches, absorbed in			
	12 hours.	24 hours.	48 hours.	72 hours.
	Grains.	Grains.	Grains.	Grains.
Siliceous sand	0	0	0	0
Gypsum powder	1	1	1	1
Calcareous sand	2	3	3	3
Arable soil	16	22	23	23
Sandy clay	21	26	28	28
Slaty marl	24	29	32	33
Loamy clay	25	30	34	35
Fine carbonate of lime	26	31	35	35
Stiff clay	30	36	40	41
Garden mould	35	45	50	52
Grey pure clay	37	42	48	49
Fine carbonate of magnesia	69	76	80	82
Humus	80	97	110	120

CHAPTER VI.

HOW TO ASCERTAIN WHETHER A SOIL IS FIT FOR THE CULTURE OF PARTICULAR CROPS—PRACTICAL INSTRUCTIONS FOR THE REGULAR AND PRECISE ANALYSIS OF SOILS — ANALYSIS OF THE SUBSTANCES IN THE SOIL WHICH ARE SOLUBLE OR INSOLUBLE IN WATER, OR IN ACIDS — EXAMINATION OF THE PARTICULAR FORMS OF ORGANIC MATTER PRESENT IN A SOIL.

In the preceding chapter I explained how any given soil could summarily, by means of a few simple experiments, be referred to its proper place in Schübler's table; but in order in a more precise manner to identify the presence, and to ascertain the amount, or proportion in weight, of each of the substances contained in a soil, a more accurate analysis is required, for it is only by such an analysis that the agriculturist can positively know what modifications he must make to the chemical constitution of a soil to render it fit for culture; whether such a constitution is naturally unfit, or has been rendered unfit, from exhaustion or otherwise, for the culture of particular crops; for it would be evidently a waste of time and of money, either, for example, to introduce into the soil such elements as it might already contain in sufficient quantity; or to attempt to grow upon it products for the existence of which certain necessary elements might be insufficient, or altogether wanting.

The manner of performing such an analysis, and the precautions which are necessary to carry it to a successful issue, will be detailed in this chapter.

The substances contained in a soil are either soluble or insoluble in water; soluble or insoluble in acids; hence three general divisions.

1st. Analysis of the substances which are soluble in water.

2nd. Analysis of the substances which are insoluble in water, but soluble in acids.

3rd. Analysis of the substances which are insoluble both in water and in acids.

Proceed therefore as follows:—

Weigh 1 lb. of the soil under examination, previously air-dried and reduced into powder by trituration in a mortar; introduce it then into a flask or capsule of suitable dimensions, with 24 ounces of hot water, and keep the whole simmering for about an hour, taking care to stir the mass from time to time, in order to promote the solution of the soluble substances contained in the soil. The most convenient way of doing this is by means of a sand bath.

Whilst the soil is digesting in the boiling water, the operator should prepare filters of suitable sizes, in order to separate the soluble from the insoluble portions, or from the precipitates which will be subsequently produced during the course of the investigation. Paper filters are made by cutting circular discs of good white blotting-paper of various dimensions (fig. 1). One of the discs is made into a filter by folding it in halves (fig. 2), and then again in quarters (fig. 3).

Fig. 1.

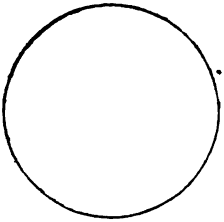


Fig. 2.

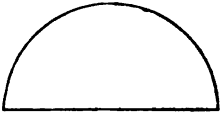
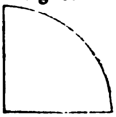
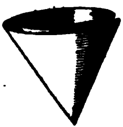


Fig. 3.



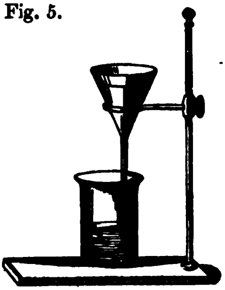
When open for filtering, it has the following appearance, (fig. 4.) The paper filter so prepared is then put into a glass funnel, which must be larger than the filter, in order that the edges of the latter should not extend beyond the brim. The funnel containing the filter is then placed in the ring of a stand, or other proper support, as represented

Fig. 4.



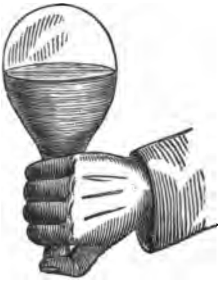
in fig. 5; and after moistening the paper filter with a little water, the whole of the contents in the flasks are poured into it, the liquor which filters being received into a glass-beaker or vessel placed under the funnel, in such a manner that the drops of liquid fall slantingly on one side of the glass-beaker or vessel, in order to prevent the splashing which the drops would make if suffered to fall in the liquid which has already filtered.

Fig. 5.



In order to empty all the contents of the flask into the paper-filter, and bring down the small portions of soil which stick to the sides of the flask, the operator should pour some water into it, and, closing its mouth with the thumb, he should quickly turn and hold it upside down as represented in fig. 6, the insoluble particles then fall into the neck, against the thumb, and on carefully removing the thumb, whilst holding the flask over the filter, they are thus easily transferred to it. If the liquid which at first passes through the filter be turbid, it must be poured back again into the filter until it passes quite clear. The insoluble portion on the filter must be washed with boiling water as long as anything continues to be dissolved. This washing is done simply by replacing, by fresh quantities of water, that which filters through. The residuum is known to be sufficiently washed when, on evaporating on a strip of platinum foil, a drop of the liquor falling from the filter, no, or only a trifling, residuum is left; which, of course, is a proof that all that which was soluble in water has been taken up.

Fig. 6.



The residuum in the filter is therefore the portion of soil which is insoluble in water; it is kept for subsequent examination, p. 83.

The liquor filtered and the washings contain all the substances soluble in water which were contained in the pound of soil operated upon.

SUBSTANCES SOLUBLE IN WATER.

Analysis of the substances in the soil which are soluble in water.

The liquor filtered from the insoluble portion, as just described, and the washings should be evaporated, so that the whole solution may be reduced to 24 fluid ounces. In order to detect the presence and estimate the amount of the soluble constituents contained therein, it should be divided, either by measure or by weight, into two equal portions, which should be kept in two separate glass-beakers, respectively distinguished by a piece of paper gummed on each, and marked solution 1 A,—solution 1 B. The first is devoted to the qualitative, the second to the quantitative analysis of the soluble substances.

QUALITATIVE ANALYSIS OF SOLUTION 1 A.

(12 fluid ounces.)

The solution 1 A should be divided into three portions.

The first portion (of 2 ounces) is devoted to the detection of the presence of *sulphuric acid* and *chlorine*.

The second portion (of 5 ounces) is devoted to the detection of *ammonia*, *silica*, *peroxyde of iron*, *oxyde of manganese*, *lime*, *magnesia*, *potash*, and *soda*.

The third portion (of 5 ounces) is devoted to the detection of *carbonic*, *nitric*, and *phosphoric acids*, and of *organic substances*.

Proceed now as follows:—

FIRST PORTION.

Take the first of these portions (2 ounces), acidify it with nitric acid, pour half of it into a test-glass, and add a solution of nitrate of baryta. If this produces a white precipitate, insoluble in water and in acids, it is sulphate of baryta, and is therefore a sign of the presence of—SULPHURIC ACID.*

To the other half add a solution of nitrate of silver; if it produces a white curdy precipitate or milkiness, immediately soluble in ammonia, it is a sign of the presence of—CHLORINE.†

SECOND PORTION.

Take now the second portion (5 fluid ounces), acidify it slightly with muriatic acid, and concentrate it by evaporation to a small bulk. In order to detect whether it contains any *ammonia*, or rather ammoniacal salts, pour a small portion of the concentrated solution into a flask, and boil it therein with a strong solution of caustic soda, or with pulverized slaked quick lime. If a slip of moistened, reddened litmus paper, held in the vapour which issues from the flask burns blue, or if a glass rod, moistened with dilute muriatic acid, and held at the mouth of the flask, produces white fumes, it is a sign of the presence of—AMMONIA.

To the remainder of the concentrated solution, acidified with muriatic acid as just mentioned, add some nitric acid, evaporate to dryness, and when dry, expose the residuum in a platinum crucible to a low red heat, in order to burn any organic matter, and to dissipate the ammoniacal salts which may be present. Drench the dry residuum which is left in the platinum crucible, after it has cooled, with muriatic acid, add water, and heat the whole; if an insoluble white powder is left, which feels gritty when rubbed with a glass rod against the sides, it is (sand)—SILICA.

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* If sulphuric acid is present, the soil contains one or more of the following sulphates, namely, sulphate of potash, of soda, or of ammonia, sulphate of magnesia and sometimes sulphate of iron. It may contain also sulphate of lime, which is sparingly soluble in water.

† If chlorine is present, it exists in the soil in the state of common salt (chloride of sodium), of calcium, of potassium, of magnesium.

The liquor containing the *silica*, in an insoluble state, must then be thrown on a filter in order to separate it, and the solution which filters through should be divided into two portions, one of which will be tested for *alumina*, *peroxyde of iron*, *manganese*, *lime*, and *magnesia;* the second for *potash* and for *soda*.

Testing the first half part of the liquor filtered from the silica.

To one of the portions of the liquor filtered from the silica add an excess of ammonia. If this produces a brown precipitate, it may consist of peroxyde of iron mixed with alumina, and possibly with manganese; but if the precipitate be white, it is due to the presence of alumina alone.

Admitting that these three substances are present, the precipitate should be collected on a filter, and then boiled with a solution of caustic potash, which dissolves the alumina, and leaves an insoluble brown residuum, which consists of—PEROXYDE OF IRON.

The potash solution, filtered from the peroxyde of iron, should be acidified with hydrochloric acid, and if the addition of ammonia produces a white gelatinous precipitate, it is—ALUMINA.

To the ammoniacal liquor, which was filtered from the precipitate of peroxyde of iron and alumina, produced by ammonia in the first instance, add a solution of hydrosulphuret of ammonia: if a precipitate of a flesh-red colour is produced, it is sulphuret of manganese, and it is a proof, of course, that the liquor contained—OXYDE OF MANGANESE.

The colour of this precipitate can seldom be observed except after the precipitate has completely settled, and it turns brown by exposure.

The sulphuret of manganese, produced by hydrosulphuret of ammonia, must now be separated by filtering, and the liquor filtered therefrom should be acidified with muriatic acid, and boiled until all odour of sulphuretted hydrogen (odour of rotten eggs) has quite vanished. In doing this the liquor will become milky, which is due to a deposition of sulphur from the decomposition of the hydrosulphuret of ammonia employed, the liquor must therefore be clarified by filtering, and the filtrate should be rendered slightly ammoniacal by pouring into it a slight excess of ammonia. If now the addition of oxalate of ammonia produces a white precipitate (either immediately or after standing for some hours), it is oxalate of lime, and it proves, therefore, that the aqueous solution of the soil contained—LIME.

The precipitated oxalate of lime should be allowed to settle well, after which the operator first filters the supernatant liquor, and finally collects the precipitate upon the filter. It is advisable to proceed in this manner, for otherwise the filtering might prove troublesome, on account of the liquor passing turbid through the filter.

The clear liquor filtered from the precipitate of oxalate of lime should next be tested with a solution of phosphate of soda; if this produces a white precipitate, it is due to the presence of—MAGNESIA.

Testing the second half part of the liquor filtered from the silica.

The second portion of the liquor, which was filtered from the silica, should be evaporated to dryness, and the dry residuum being transferred to a small platinum crucible, is kept at a red heat until all the volatile and organic matter has been expelled or reduced to ashes; the ashes or residue thus left should be moistened with a little water, and alcohol being added and stirred about is set on fire; if the flame has a strong yellow colour, it is due to the presence of—SODA.

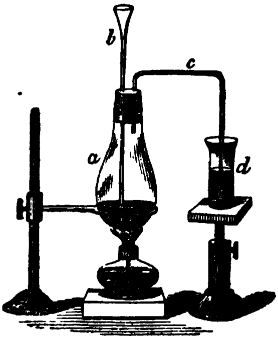
THIRD PORTION.

After having ascertained the presence or absence of soda as just said, the residue which is still left should be redissolved in as small a quantity of muriatic acid as possible, and bichloride of platinum being added, the whole is evaporated to dryness in a water-bath. Alcohol should then be poured upon the residue, and if an insoluble yellow powder is left, it is a double chloride of potassium and platinum, and it indicates, of course, the presence of—POTASH.

The third portion of the liquor containing the whole of the soluble substances being devoted to the detection of *carbonic, nitric, phosphoric acids*, and of *organic substances*, should be divided into four parts, each of which is tested separately for those compounds.

Testing the first of these four parts for carbonic acid.

The solution should first be tested with reddened litmus paper, and with yellow turmeric paper; if, on dipping these papers in the solution, the first turns blue and the second brown, it is a proof that the liquor is alkaline, and that it consequently contains a carbonate of alkali, such as *carbonate of potash* or *soda*, or of *ammonia;* and if the proportion of these carbonates is at all considerable, which however is seldom the case, an effervescence will be produced on pouring muriatic acid in the solution. Yet carbonates of alkalies might be present to a pretty large amount, and yet no effervescence be produced, because the carbonic acid eliminated by the acid remains dissolved in the liquor; it is therefore better to proceed as follows:—



Pour the liquor into the flask *a* provided with a tube funnel terminated in a point, and with a tube *c* bent twice at right angle, as in the figure, and plunging into a glass-beaker containing lime-water. An excess of muriatic acid is then poured into the flask *a* through the tube funnel *b*, and a gentle heat is applied. If the solution in the flask *a* contains any carbonic acid, a white precipitate of carbonate of lime will be produced in the lime-water contained in the glass-beaker *d*, showing that the soil contained—CARBONIC ACID; and as the carbonates of alkalies alone are soluble in water, it existed in combination with potash, soda, or ammonia, the presence of which may have been already detected by previous experiments.

[Lime-water, it must be recollected, if left exposed to the air, is soon covered with little scales of carbonate of lime, from the absorption of the carbonic acid of the air; it is therefore advisable, in order to avoid all source of error, to pour a small quantity of oil upon the surface of the lime-water, in the glass-beaker *d*, which, of course, shelters it from the contact of the air.]

Testing the second part of the third portion for nitric acid.

Nitric acid, or rather its combination with bases in the state of nitrates, is rarely found present in our soils, except as a trace; and consequently its detection is sometimes difficult or doubtful. The best way consists in evaporating the solution to a small bulk, adding to the very concentrated liquor a drop of solution of sulphate of indigo, a few drops of a solution of common salt, and likewise a few drops of concentrated sulphuric acid. The whole being now boiled, if the blue colour imparted by the solution of the sulphate of indigo disappears, it is a sign of the presence of—NITRIC ACID.

All nitrates are soluble in water.

Testing the third part of the third portion for phosphoric acid.

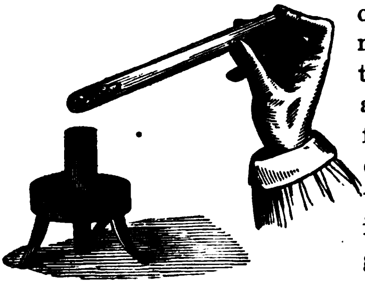
The quantity of soluble phosphate in soils being always excessively small, may easily be overlooked, and therefore the operator must proceed with great care. In order to ascertain whether phosphoric acid, that is a soluble phosphate, is present, the solution under examination should be poured into a glass-beaker, an excess of acetic acid poured into it, and likewise a small quantity of perchloride of iron; as the quantity of perchloride of iron should be very small, the operator had better moisten a glass rod with the solution of perchloride of iron, and stir the liquor with it. If now the addition of an excess of acetate of soda produces a gelatinous flaky precipitate, it is a sign of the presence of—

PHOSPHORIC ACID.

If the proportion of phosphate in the soil is very small, the operator must not be in a hurry to conclude that no phosphoric acid is present, because 12, 15, or even 24 hours are sometimes necessary for the production of that precipitate.

Testing the fourth, or last part of the third portion for organic substances.

In order to detect the presence of organic substances, evaporate the solution to dryness in the oil-bath; when dry transfer the residuum to a tube of German glass, and ignite it therein, holding it over the flame of an argand spirit lamp, (or, if coal gas is used, hold it in the flame of my gas furnace); whilst heating it let a strip of moistened reddened litmus paper be engaged into the upper portion of the tube, and maintained there by the finger which stops the mouth of the tube. If the mass in the tube becomes charred, it is a proof that an organic matter is present; and if, whilst heating it, an odour of burnt feathers is evolved, or if the strip of reddened litmus paper turns blue, the organic matter contains nitrogen, resolvable into ammonia. In either



case the experiment will show the presence or absence of—
ORGANIC MATTER.

QUANTITATIVE ANALYSIS OF THE SOLUTION 1 B.

(12 *ounces.*)

Having ascertained, by the experiments detailed in the qualitative examination of solution 1 A, what soluble substances are present in the soil, there remains to ascertain their amount or proportion.

Proceed therefore as follows :—

The solution 1 B should be divided into 4 portions.

The 1st portion (of 2 oz.) is devoted to the estimation of the *whole amount of soluble matter* in the soil, of *ammonia, nitric acid*, and organic substances.

The 2nd portion (of 2 oz.) is devoted to the estimation of *sulphuric acid* and of *chlorine.*

The 3rd portion (of 2 oz.) is devoted to the estimation of *carbonic acid.*

The 4th portion (of 6 oz.) is devoted to the estimation of *silicic acid, phosphoric acid, peroxyde of iron, alumina, manganese, lime, magnesia, potash, and soda.*

FIRST PORTION OF SOLUTION 1 B.—(2 *oz.*)

Estimation of organic matter and volatile salts.

If the operator does not wish to ascertain separately the amount of ammoniacal salts, or if, which generally is the case, the aqueous solution of the soil contains only a trace of such salts, he may at once treat the portion of solution now under examination in the following manner :—

The first portion of solution 1 B just mentioned, is carefully evaporated to dryness in a steam or oil-bath at a temperature of 212°, weighed, replaced on the bath, weighed again, and so on, until it is found that the weight remains the same. The weight thus obtained represents of course the whole of the substances soluble in water contained in that fourth part of the solution, which is, in fact, the eighth part of the whole solution; the loss, of course, is moisture. The dry residuum is then transferred to a platinum crucible, and kept therein at a low red heat until all the organic matter is entirely burnt off, which is known by the mass being completely converted into ashes, the loss is then taken account of as—ORGANIC MATTER AND VOLATILE SALTS.

The operator must not forget that the whole solution of the soluble substances in the pound of soil was divided into two equal portions (solution 1 A, and solution 1 B); and that the experiment just explained having been performed upon one fourth part only of the solution 1 B, the results obtained are in reality *the eighth part of the whole,* and should accordingly be muliplied by eight, to express the quantity contained in the pound of soil, thus:—

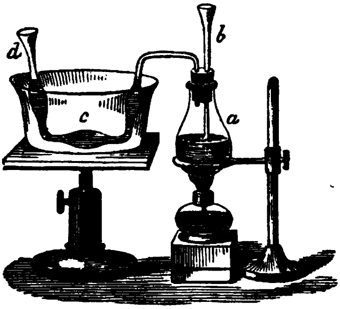
Let us suppose, for example, that the weight of the residuum left after evaporating to dryness the above-said fourth part of the first portion of solution 1 B, is 13 grains; 13 multiplied by 8 is 104. The pound (7000 grains) of soil operated upon contains, therefore, 104 grains of soluble matter.

Let us suppose, moreover, that the 13 grains just mentioned lost 2 grains by ignition in the platinum crucible, we shall have—

Of soluble fixed saline matter	11 grains	multiplied	by 8= 88
Of organic matter and volatile salts . . .	2 do.	do.	by 8= 16
	13 grains	do.	8=104

The 7000 grains (1 pound) of soil operated upon, contained therefore 88 grains of fixed soluble salts, and 16 grains of organic matter and volatile salts.

If, however, the quantity of ammonia existing in the soil is more considerable, or if the operator wishes to determine separately the proportion of ammonia, the first portion of solution 1 B just mentioned should be introduced into a



flask *a*, provided with a perfectly sound cork perforated with two holes, through one of which a funnel tube *b*, terminated by a capillary point, passes and plunges into the solution in the flask; through the other hole, one of the extremities of a bulb-condenser *c* is adjusted. The condenser is filled with dilute muriatic acid, and is kept upright by placing it into a basin or vessel of suitable dimensions. This condenser should be filled with muriatic acid before connecting it, which is easily done by plunging one of its extremities into a certain quantity of acid, and sucking it up, by applying the lips at the other extremity. The apparatus being connected and air-tight, an excess of a strong solution of caustic soda is poured into the flask *a*, through the tube-funnel *b*, and heat is applied by means of a spirit lamp. The ammonia, which is liberated by this treatment, is taken up by the muriatic acid in the bulb-condenser where it is transformed into sal-ammoniac, which remains in solution; when all the ammonia has been evolved, the operator must apply his lips to the extremity *c* of the condenser, and suck the air, which, entering by the funnel *b*, sweeps the apparatus, so that the ammonia contained in the flask above the liquid is thus made to traverse the condenser, where it is retained or fixed. This being done, the bulb-condenser may be disconnected, its contents are transferred to a capsule, and evaporated therein to dryness in the *water-bath*. The capsule containing the dry residuum is then weighed, after which it is replaced in the water-bath for one hour, and weighed again; if this second weighing agrees with the first, the operation is terminated, otherwise the heat must be continued until two weighings are found to be uniform. The residuum consists of sal ammoniac, 54 grains of which represent 17 of ammonia.

The quantity of ammonia ultimately found out by calculation, being multiplied by 8, gives the proportion contained in the pound of soil operated upon.

Instead of evaporating the solution containing the sal-ammoniac, it is simpler, and at the same time quicker to charge the condenser with a known quantity of muriatic acid of a known strength, and subsequently to test how much muriatic acid is left unsaturated, by means of a solution of ammonia, also of a known strength. This method is fully described, both in my "Guide to the Alkalimetrical Chest," and in my "Commercial Hand-book of Chemical Analysis," to which the reader is referred.

SECOND PORTION OF SOLUTION 1 B.—(2 *oz.*)

Estimation of sulphuric acid and of chlorine.

The second portion of solution 1 B should be concentrated by evaporation, acidified with nitric acid, and then divided into 2 parts.

Pour into one of these two parts a solution of nitrate of baryta as long as a white precipitate continues to be produced; the precipitate, which is sulphate of baryta, should then be collected on a filter, thoroughly washed, dried, heated to redness in a platinum crucible, and weighed.

117 grains of sulphate of baryta represent:—

40 grains of sulphuric acid; or
88 do. of sulphate of potash.
72 do. of sulphate of soda (Glauber's salts, dry),
60 do. of sulphate of magnesia (Epsom salts, dry),
68 do. of sulphate of lime (plaster),
68 do. of sulphate of iron (green copperas, dry.)

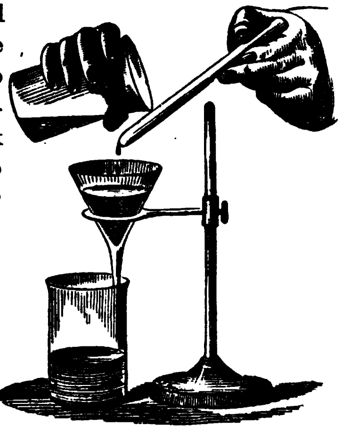
Pour into the second part of the liquor, acidified by nitric acid, a solution of nitrate of silver as long as a precipitate is produced, boil the whole for a few minutes, in order to agglomerate the precipitate, which is chloride of silver, throw the whole on a filter, wash the precipitate on the filter thoroughly, and dry it on the filter. This is done in the following manner:—

The filter containing the precipitated chloride of silver, having been allowed to drain well, is carefully opened flat upon a piece of absorbing ware and dried; when dry the precipitate should be scraped carefully from the filter into a small porcelain crucible, the filter, being burnt on the cover of the crucible and its ashes added to the mass in the small crucible, it is then carefully fused, and after cooling it is weighed.

144 grains of chloride of silver represent:—

36 grains of chlorine ; or
60 do. of chloride of sodium (common salt),
56 do. of chloride of calcium
76 do. of chloride of potassium,
48 do. of chloride of magnesium.

When precipitates have to be separated by filtering, and in fact when a liquor is to be poured from one vessel into another, it is generally advisable, in order to avoid the risk of losing any portion of it, to rub the rim of the beaker from which the liquor is poured with a piece of tallow-candle, by which means the liquid is prevented from trickling outside, and can be poured out clean; and even though the rim of the vessel is greased, it is well, as an



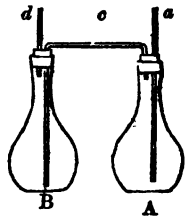
extra precaution, to pour the liquid down a moistened glass-rod as represented in the above fig. For washing precipitates, a washing bottle should be employed. That which I use in my laboratory is represented here, it differs from other washing bottles only in this, that the tubes *a* and *b*, being much shorter than usual, are much less in the way and less exposed to be broken. By blowing at *b*, a very strong jet of water issues forth at *a*, by which the sides of the paper-filter may be washed out clean. A precipitate is known to be sufficiently washed when one of the drops which percolate through the filter being evaporated on a strip of platinum foil, leaves no residuum, or only an insignificant one.

THIRD PORTION OF SOLUTION 1 B.—(2 *oz.*)

Estimation of carbonic acid.

The third portion of solution 1 B may often be neglected, for it seldom happens that it contains alkaline carbonates in solution, at least in sufficient quantities to be estimated, in which case it may be mixed with the fourth portion. If, however, the qualitative analysis has shown that they exist in the solution in a notable proportion, the best way of estimating their amount is by Drs. Fresenius and Wills' process. In that case the solution should be reduced by evaporation to about 1 ounce, and introduced into the flask A of the following apparatus, which consists of 2 flasks, A and B.

The first must have a capacity of from two to two ounces and a half; the second, or flask B, should be of a smaller size, and hold from one ounce and a half to two ounces. Both flasks must be provided with perfectly sound corks, *Fig.* 7.



each perforated with two holes through which the tubes *a*, *c*, *d*, are passing. The lower extremity of the tube *a* must be so adjusted as to reach nearly to the bottom of the flask A, and its upper extremity is closed at *b* by means of a small pellet of wax; *c* is a tube bent twice at right angles, one end of which merely protrudes through the cork into the flask A, but the other end reaches nearly to the bottom of the flask B. The tube *d* of the flask B merely protrudes through the cork into the flask.

The apparatus being disposed as just said, the concentrated solution above alluded to is introduced into the flask A, and concentrated sulphuric acid is poured into the other flask B; the corks are then put in both flasks, when they become connected so as to form a twin apparatus, and the whole is accurately weighed in a delicate balance.

The weight of the apparatus being noted down, the operator should now apply his lips to the extremity of the tube *d*, and suck out a few air bubbles which rarefies the air in the flask A, and consequently causes the sulphuric acid of the flask B to ascend a certain height (after the suction) into the tube *c*; if after a short time the column of sulphuric acid maintains its height in the tube *c*, it is a proof that the apparatus is air-tight, and therefore as it should be. This being ascertained, suction is again applied to the extremity of the tube *d*, so that a portion of the sulphuric acid of the flask B ascends into the tube *c*, and presently falls into the flask A, the quantity which thus flows over being proportionate to the vacuum produced by suction. As soon as the acid comes in contact with the carbonate in the flask A, carbonic acid is disengaged, and in order to escape it must pass by the tube *c*, through the concentrated sulphuric acid of the flask B, by which it is completely dried before it finally escapes through the tube *d*. The effervescence produced by the disengagement of the carbonic acid having subsided, suction is again applied to the tube *d*, in order to cause a fresh quantity of sulphuric acid to flow over into the flask as before, and so on, until the carbonate being completely decomposed, carbonic acid ceases to be evolved. When this point is obtained, a powerful suction is applied to the tube *d*, in order to cause a tolerably large quantity of acid to flow into the flask A, which thus becomes very hot, from the combination of the concentrated acid with the water, so that the carbonic acid is thoroughly disengaged from the solution.

When all evolution of carbonic acid gas has ceased, the little stopper of wax is carefully removed from the tube C, and suction applied for some time, in order to remove the carbonic acid contained in the flasks and replace it by atmospheric air. When the apparatus has become quite cold it is weighed again, the difference of weight between this second weighing and the first, that is to say, the *loss*, indicates of course the quantity of carbonic acid which was contained in the carbonate and which has escaped, from which, of course, the quantity of the carbonated alkali operated upon may be calculated.

22 grains of loss represent:—

22 grains of carbonic acid, or
54 do. of carbonate of soda,
70 do. of carbonate of potash,
59 do. of sesquicarbonate of ammonia.

In sucking the air from the bottle, the operator should take care that his lips be dry, or else a quantity of saliva might run down the tube, and, augmenting the weight of the apparatus, spoil the experiment.

FOURTH PORTION OF SOLUTION 1 B.—(6 *oz.*)

Estimation of silica, peroxyde of iron, alumina, manganese, lime, magnesia, potash, soda, and phosphoric acid.

The 4th portion of solution 1 B should now be mixed with an excess of muriatic acid, and evaporated to *perfect* dryness in the water-bath. During the evaporation the silica forms a jelly, which must be thoroughly dried, for which purpose the capsule containing it should be at last heated in a sand or oil bath at about 300° Fahr. The perfectly dry residuum thus obtained should now be drenched with hydrochloric acid, and water being added, the whole is gently heated. The insoluble gritty residuum is silica; it must be collected on a filter, thoroughly dried, heated red-hot, and then weighed in the state of—SILICA.

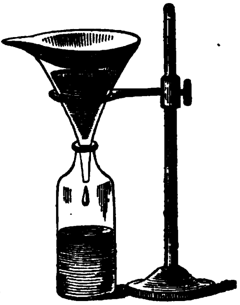
[Before exposing the silica, isolated as just said, to a red heat, take care that it is *perfectly* dry, for otherwise it would be projected as dust out of the crucible, and a loss would thus be sustained. The crucible should be closed with a tight cover, and, without removing it, the whole is weighed after cooling. If the crucible were removed, the silica would attract moisture from the air and give an incorrect weight.]

The liquor filtered from the *silica* must now be analyzed, for which purpose it should be divided into 3 parts.

FIRST PART OF THE FOURTH PORTION OF SOLUTION 1 B FILTERED FROM THE SILICA.

Estimation of peroxyde of iron, alumina, lime, and manganese.

To the liquor under examination, and which contains an excess of muriatic acid, add an excess of ammonia, and stir the whole well. This will precipitate both the peroxyde of iron and alumina, which should be collected on a filter and washed thereon, taking care to avoid the contact of the air as much as possible during the filtering, which is easily accomplished by covering the funnel with a plate of glass, or with a capsule, as represented in the figure. The precipitate on the filter should then be boiled with a large excess of caustic potash which redissolves the alumina and leaves the iron in an insoluble state. As the alumina is gradually dissolving in the solution of caustic potash, the precipitate becomes much darker, and



at last consists altogether of peroxyde of iron. The whole should then be be thrown upon a filter, which will retain, of course, all the peroxyde of iron, which should be well washed with hot water, dried, exposed to a red heat, and weighed. After ignition the mass is almost black, and is—PEROXYDE OF IRON.

[Considering that when peroxyde of iron has been precipitated by potash it is very difficult to wash it clean, and that it always retains a small proportion of potash, it is better to redissolve it whilst moist in muriatic acid, and to reprecipitate it by ammonia, filtering, washing, drying, igniting, and finally weighing it.]

The alkaline liquor which was filtered from the peroxyde of iron should be slightly supersaturated with muriatic acid, and the alumina which it contains is precipitated by pouring into the liquor a solution of carbonate of ammonia, and it may then be collected on a filter. The precipitate is difficult to wash, for which purpose it is advisable to use boiling water. It is bulky, but it contracts in an extraordinary manner in drying. When dry it must be exposed to a red heat and then weighed—it is ALUMINA.

[The only difficulty which the operator may encounter in the above process, by which alumina is separated from peroxyde of iron, is respecting the quantity of potash which should be employed; it is only after having filtered the liquor from the peroxyde of iron that he can know whether the quantity of potash used has been sufficient. This is ascertained by letting a drop of muriatic acid fall in the liquor. If the small cloud produced disappears by stirring the liquor, there is an excess of potash, and it is all right; if, on the contrary, the little cloud remains permanent, the peroxyde of iron in the filter must be boiled again with a fresh quantity of potash. However, in a great number of cases the quantity of alumina and of peroxyde of iron is so small that they need not be separated, the precipitate produced by ammonia being at once washed, dried, ignited, weighed, and taken account of as peroxyde of iron and alumina.]

To the ammoniacal liquor which was filtered from the precipitate of oxyde of iron and alumina produced by an excess of ammonia, add oxalate of ammonia; this will produce a precipitate of oxalate of lime, which should be allowed to settle well by leaving the liquor at rest in a warm place for ten or twelve hours. The precipitate is then collected on a filter, washed, dried, and exposed to a red heat in a platinum crucible, which converts it into *carbonate of lime*, in which state it is weighed.

50 grains of carbonate of lime represent 28 grains of—
LIME.
68 grains of sulphate of lime, or
56 do. of chloride of calcium, or
82 do. of nitrate of lime.

On exposing oxalate of lime to a red heat as just said, it first becomes grey, but by continuing the heat, it becomes white again, which is a sign that it has been heated long enough. As however it might happen that a portion should have passed into the state of quick-lime, which would give an incorrect result, it is best, in order to guard against this chance of error, to moisten the residuum in the crucible with a few drops of a strong solution of carbonate of ammonia, and again to apply first a gentle heat gradually increasing to a dull red heat visible in the dark, and then to weigh the residuum again, which is then sure to be—CARBONATE OF LIME.

To the liquor filtered from the precipitate of oxalate of lime, add hydrosulphuret of ammonia, which will precipitate the manganese in the state of sulphuret of manganese, which should be collected on a filter, and washed with water containing a little hydrosulphuret of ammonia. The operator should now burst a hole through the filter with a glass rod, and wash the precipitate in the filter down into a glass-beaker by blowing a jet of water from the washing bottle, as represented in the figure; muriatic acid is poured into the beaker

in order to dissolve the precipitate, and the whole is boiled until all odour of sulphuretted hydrogen has vanished. The acid solution of the manganese is then poured into a porcelain capsule, an excess of carbonate of soda is added, and the whole is boiled, or even evaporated to dryness at a gentle heat, in order to avoid spirting. Hot water is poured upon the residuum, and the insoluble portion is carbonate of manganese, which should be well washed, dried, and kept for some time at a bright red heat, in order to expel the carbonic acid and convert it into red oxyde of manganese (manganoso-manganic oxyde) in which state it is weighed.

116 grains of red oxyde of manganese represent 36 of—
PROTOXYDE OF MANGANESE.

SECOND PART OF THE FOURTH PORTION OF SOLUTION 1 B FILTERED FROM THE SILICA.

Estimation of magnesia, potash, and soda.

To the liquor under examination, and which contains an excess of muriatic acid, add a solution of sal-ammoniac, and then an excess of solution of carbonate of ammonia, mixed with caustic ammonia; this will precipitate the peroxyde of iron, alumina, lime, and manganese; a gentle heat should be applied, and the whole thrown upon a filter and washed. The liquor which filters through should then be evaporated to dryness and exposed to a dull red heat, in order to expel the ammoniacal salts. The residue consists then of chlorides of magnesium, potassium, and sodium, which should be dissolved in a small quantity of water. Yet, as there is always a small portion of magnesia, which, from having lost some of its acid, is left in an insoluble state, a drop or two of muriatic acid should be added to dissolve it. An excess of pure peroxyde of mercury should now be added to the solution, and the whole be again evaporated to dryness. The chloride of magnesium is then decomposed and converted into pure magnesia, whilst at the same time perchloride of mercury (corrosive sublimate) is formed, which combines with the chlorides of potassium and of sodium, forming with them a double salt. The dry mass is then treated by water, thrown upon a filter, washed until the filtrate ceases to be precipitated by nitrate of silver; the magnesia on the filter, which retains oxyde of mercury, must be exposed to a red heat in order to expel the latter, and it is weighed.

20 grains of MAGNESIA represent:—

48 grains of chloride of magnesium, or
60 do. of sulphate of magnesia.

The solution filtered from the magnesia should be evaporated to dryness, and the residuum exposed to a dull red heat, in order to expel and volatilize the chloride of mercury; the chlorides of potassium and of sodium, which remain, may then be weighed conjointly. If, however, the operator wishes to ascertain the weight of each separately, he must proceed as follows:—Dissolve the mixed chlorides in the platinum crucible in a small quantity of water, and add thereto an excess of perchloride of platinum, and evaporate the whole to dryness in the water-bath. Upon the dry mass pour spirits of wine, of specific gravity 0·896, that is about 30° over proof, or containing 80 per cent. of alcohol, and leave the whole to digest for some time. The insoluble portion is a double chloride of platinum and potassium, which should be collected on a filter, washed with spirits of wine of the strength above mentioned, dried at a gentle heat, and then weighed.

247 grains of potassio-chloride of platinum represent:—

48	grains	of POTASH, or
76	do.	of chloride of potassium,
88	do.	of sulphate of potash,
102	do.	of nitrate of potash,
70	do.	of carbonate of potash, &c.

As the residuum left after the separation of the magnesia consisted of chloride of potassium and of chloride of sodium, which chlorides have been weighed conjointly, if the proportion of chloride of potassium found be subtracted from the joint weight, the difference indicates the weight of the chloride of sodium.

60 grains of chloride of sodium represent:—

32	grains	of SODA, or
72	do.	of sulphate of soda,
86	do.	of nitrate of soda,
54	do.	of carbonate of soda.

THIRD AND LAST PART OF THE FOURTH PORTION OF SOLUTION 1 B FILTERED FROM THE SILICA.

Estimation of phosphoric acid.

To the liquor under examination, and which contains a slight excess of muriatic acid, add a few drops of perchloride of iron. (If in the preceding operations iron has been found, this addition of perchloride of iron may be dispensed with, but in that case the liquor should be boiled with a little nitric acid, in order to ensure the peroxydization of the iron.) Having done this, add an excess of acetate of soda. If the liquor assumes a red colour, it is well; if it does not do so, solution of perchloride of iron must be added, drop by drop, until it does. The whole is then transferred to a flask of suitable size, and gently boiled therein for five or six minutes, which produces a reddish brown precipitate. The liquor above this precipitate should be colourless; if it has a brown colour, it is a proof that the quantity of acetate of soda employed was not sufficient, and more of it must be added. The whole is then thrown upon a filter, the precipitate is washed thereon with boiling water, after which it is transferred, whilst still moist, to a glass-beaker, and dissolved therein with muriatic acid; tartaric acid is then added, the whole is stirred, and an excess of ammonia is then poured in, so that the precipitate at first produced is redissolved by the excess of ammonia. A slight excess of acetate of lead is added to the solution, which produces a precipitate of phosphate of lead, which should be separated and dissolved with as little nitric acid as possible, and a slight excess of basic acetate of lead is added, which produces a precipitate of phosphate and of basic nitrate of lead, which should be collected on a filter, washed, dried, exposed to a red heat, and weighed. The dry mass in the crucible, and the crucible containing it, are then put into a glass-beaker and dissolved therein at a gentle heat with dilute nitric acid; the crucible is withdrawn and washed, the washings being of course added to the liquid in the glass-beaker, and an excess of pure moderately dilute sulphuric acid and alcohol is added, in order to precipitate the lead as sulphate of lead, which is allowed to settle perfectly and then collected on a filter, washed with spirits of wine, dried, and ignited in a porcelain crucible. The difference between this weight and that of the mass in the crucible is—PHOSPHORIC ACID.

152 grains of sulphate of lead contain 112 grains of oxyde of lead, and represent therefore, 36 grains of phosphoric acid.

SUBSTANCES INSOLUBLE IN WATER, SOLUBLE IN MURIATIC ACID.

The insoluble mass which was left in the filter, after treating the pound of soil with water, and which was kept for further examination, is now to be analyzed; for which purpose take 200 grains of it, dry them, weigh them, and then expose them for some time to a red heat, stirring all the while, until all the organic matter is destroyed, the weight of which is indicated by the loss.

The mass left after the destruction of the organic matter, being accurately weighed, should now be introduced into a flask with enough water to form a thin paste, a gentle heat is applied, an excess of muriatic acid is gradually added to the mass, and the whole is left to digest at a nearly simmering heat for one or two hours, shaking the flask occasionally in order to promote the solution; at the end of that time the whole is thrown upon a filter, and the insoluble portion is washed with water until completely exhausted, and kept for future examination.

The liquor filtered from the mass which remained undissolved by muriatic acid should be divided into two portions, respectively marked solution 2 A., and solution 2 B. The first is devoted to the qualitative, the second to the quantitative analysis of the substances of the soil which are soluble in muriatic acid.

QUALITATIVE ANALYSIS OF SOLUTION 2 A OF SUBSTANCES INSOLUBLE IN WATER, SOLUBLE IN MURIATIC ACID.

The solution 2 A should be divided into two parts.

The first part is devoted to the detection of the presence of *sulphuric acid*, *protoxyde* and *peroxyde of iron*.

The second part is devoted to the detection of *silica*, *phosphoric acid*, *lime*, *magnesia*, *potash*, *soda*, *manganese*, and *alumina*.

FIRST PART.

Divide this first part into three portions.

If, on adding to this first portion a solution of chloride of barium, a white precipitate, insoluble in water and in acids is produced, it is sulphate of baryta, which of course indicates the presence of—SULPHURIC ACID.

If the second portion, being first diluted with a large quantity of water, and then tested with ferricyanide of potassium, produces a dark blue precipitate, it indicates the presence of—PROTOXYDE OF IRON.

If the third portion, also largely diluted with water, being tested with a solution of ferrocyanide of potassium, produces likewise a dark blue precipitate, it indicates the presence of—PEROXYDE OF IRON.

SECOND PART OF SOLUTION 2 A.

To the second part of solution 2 A, a little nitric acid is added, and the whole is evaporated to perfect dryness. The dry mass is then drenched with concentrated muriatic acid, water is added, and if an insoluble perfectly white, gritty residuum remains, it is—SILICA.

The *silica* is separated by filtering, and the liquor filtered from it is divided into two portions.

The first portion of the liquor filtered from the silica is devoted to the detection of *phosporic acid, lime,* and *magnesia.*

The second portion of the liquor filtered from the silica is devoted to the detection of *potash, soda, manganese,* and *alumina.*

To the first portion of the liquor filtered from the silica, add a few drops of perchloride of iron, which, however, may be dispensed with if iron has been detected before; pour ammonia into the liquor until a precipitate begins to appear, and likewise some acetic acid, then an excess of acetate of soda, and boil the whole for a little time. A reddish-brown precipitate is produced, and the supernatant liquor is colourless. If it retains a brown colour, more acetate of soda must be poured in, and the whole boiled again. This supernatant liquor is decanted or filtered from the brown precipitate (which contains all the phosphoric acid in the state of perphosphate of iron), and is afterwards tested for lime and magnesia. The precipitate produced should then be collected on a filter, washed with boiling water, and then transferred with the filter to a beaker, and dissolved therein with muriatic acid. When it has completely dissolved, the solution must be diluted with water, the acid neutralized with ammonia, and the iron is precipitated in the state of black sulphuret, by adding an excess of hydrosulphuret of ammonia. The sulphuret of iron is separated by filtering, the filtered liquor is evaporated to a small bulk, and if the addition of sulphate of magnesia produces, after some time, and especially by stirring, a white crystalline precipitate, it indicates the presence of—PHOSPHORIC ACID.

To the liquor which was filtered from the perphosphate of iron, produced as just mentioned, oxalate of ammonia is added; if this produces a white precipitate, it is oxalate of lime, and it indicates of course the presence of—LIME.

The oxalate of lime is collected on a filter, and if, to the liquor which filters from it, a solution of phosphate of soda being added, produces a white precipitate, it is ammonia, if phosphate of magnesia be added, it indicates the presence of—MAGNESIA.

The second portion of the liquor filtered from the silica should be evaporated to dryness, and the dry residuum exposed at a low red heat, in order to volatilize the ammoniacal salts; the residue is then dissolved in a small quantity of water, an excess of baryta-water is poured in, and the whole is boiled. This produces a precipitate which must be separated by filtering, and is subsequently tested for *manganese* and *alumina*. To the liquor which filters from that precipitate, a solution of carbonate of ammonia is added, which produces again a precipitate due to the excess of baryta-water employed, and to the lime which may be present, and which are thus converted into insoluble carbonates; the whole is thrown upon a filter, the filtered liquor is evaporated to dryness, and exposed to a low red heat.

If a portion of the dry residuum, heated before the blowpipe upon the hook of a perfectly clean platinum wire, produces a strong yellow flame, it is a sign of the presence of—SODA.

If the residuum treated with bichloride of platinum (page 81), produces the characteristic yellow precipitate, it indicates the presence of—POTASH.

[Care must be taken that all the ammoniacal salts have been eliminated by ignition, for ammonia produces, with bichloride of platinum, a yellow precipitate, which might be mistaken for potash.]

A small portion of the precipitate produced by the baryta-water (page 86), should now be mixed with a little carbonate of soda, and heated in a small capsule or spoon of platinum, before the outer flame of the blow-pipe; if a *green* manganate of soda is then found, it indicates the presence of—MANGANESE.

The remainder of the precipitate produced by baryta water (p. 86), should now be boiled with an excess of caustic potash, and filtered. If the filtrate, being first neutralized by muriatic acid, produces a white gelatinous precipitate, on adding ammonia, it is a sign of the presence of—ALUMINA.

If CARBONATES are present, an effervescence will have been produced, on first treating the portion of soil insoluble in water with muriatic acid, which effervescence of course was due to a disengagement of—CARBONIC ACID.

QUANTITATIVE ANALYSIS OF SOLUTION 2 B, CONTAINING THE SUBSTANCES INSOLUBLE IN WATER, SOLUBLE IN MURIATIC ACID.

The whole of this solution, previously mixed with nitric acid, should be transferred to a porcelain dish, and evaporated to perfect dryness; the dry residuum being drenched with muriatic acid and allowed to digest for about half an hour, after which water is added, the insoluble residue which should be perfectly white is collected on a filter, washed until the liquor filters free from acid reaction; it is then dried, exposed to a red heat, and weighed as—SILICA.

This silica proceeds generally from the *silicates of iron* and of *alumina* in the soil.

The liquor filtered from the silica should then be divided into three portions.

The first portion is devoted to the *estimation of sulphuric acid.*

To the first portion filtered from the *silica* (which need not be more than one-fifth of the whole) add nitrate of baryta, collect the precipitate on the filter; wash, dry, ignite exactly as described (p. 72), and weigh.

117 grains of sulphate of baryta represent:—

40 grains of SULPHURIC ACID, or
68 do. of sulphate of lime.

Sulphate of lime is probably the only sulphate that may be present, since all the other sulphates are soluble in water except sulphate of baryta and of strontia; but these cannot be present at any rate in this portion of the soil, since they are likewise insoluble in acids. Even sulphate of lime, being soluble in 400 parts of water, will probably have been dissolved with the other substances soluble in water.

To the second portion of the liquor filtered from the silica (one-third of the whole) add a solution of sal-ammoniac and of ammonia, which will precipitate the *iron* and *alumina.* The precipitate is collected on a filter, washed, and then boiled with caustic potash, which dissolves the alumina and leaves the peroxyde of iron. The alumina is estimated exactly as was described (p. 78)—ALUMINA.

The peroxyde of iron, which was left in an insoluble state after boiling with potash in order to dissolve the alumina, which peroxyde of iron was collected and washed on the filter, should be dissolved on that filter by pouring muriatic acid upon it, and the filter should be well washed with water. To this strongly acid solution ammonia is cautiously added, so that the acid may be neutralized, for which purpose dilute ammonia only should be used towards the end. The ammonia should be added, only until a few flakes of peroxyde of iron (reddish brown) begin to appear, and remain permanently floating about after shaking. If this point is overdone, a drop of dilute muriatic acid may be added, and the liquor is well stirred. A solution of neutral succinate of ammonia is then added, as long as a light brown precipitate of peroxyde of iron is produced. After allowing the precipitate to settle well, it is collected, when perfectly cold, on a filter, and washed thoroughly with cold water, for hot water often decomposes it, and dissolves an acid persuccinate of iron; after washing this precipitate thoroughly, it should be dried and ignited in a platinum crucible, and then weighed as—PEROXYDE OF IRON.

[As this precipitate of persuccinate of iron is exceedingly bulky and difficult to wash, the greatest part of the succinic acid may be removed by pouring dilute ammonia on the precipitate, after washing on the filter. The ammonia takes up the succinic acid, and the precipitate of iron becomes much darker in consequence. If the dilute ammonia employed is warm, the effect produced is more complete.]

The liquor filtered from the peroxyde of iron is mixed with the other solution, which was filtered from the mixed precipitate of peroxyde of iron and of alumina produced in the first instance, and oxalate of ammonia is added, which will precipitate the lime in the state of oxalate of lime, which should be collected on a filter, washed, dried, and ignited, as described, p. 79; it is then weighed as carbonate of lime.

50 grains of carbonate of lime represent 28 grains of—LIME.

[The lime existed in the soil in the state of carbonate or of silicate of lime].

To the liquor filtered from the precipitated oxalate of lime, hydrosulphuret of ammonia is added, which precipitates the manganese as sulphuret of manganese, in the manner described page 80—MANGANESE.

The liquor filtered from the sulphuret of manganese is acidified by muriatic acid, and boiled until all odour of sulphuretted hydrogen has disappeared. It turns milky from the separation of sulphur from the decomposition of the hydrosulphuret of ammonia employed in the preceding experiment. When all odour has disappeared, it is filtered to remove the sulphur, evaporated to dryness, and the dry residuum is exposed to a dull red heat, in order to expel the ammoniacal salts. The residue consists of chlorides of magnesium, potassium, and sodium, which are estimated as described page 81—MAGNESESIA, POTASH, SODA.

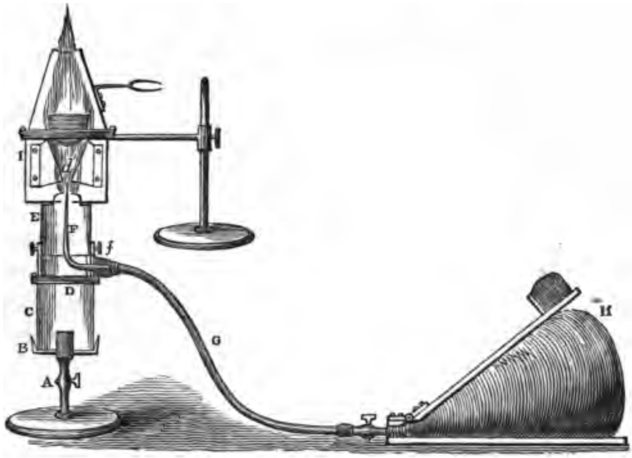
The third portion of the liquor filtered from the silica, is altogether devoted to the estimation of phosphoric acid, which is done exactly as described page 82.—PHOSPHORIC ACID.

If the portion of soil submitted to the action of muriatic acid has effervesced, it is due to a disengagement of carbonic acid, the amount of which may be determined exactly as described page 74, taking a fresh portion of soil (100 grains) for the purpose. Carbonic acid may exist in the soil as carbonate of lime or of magnesia.

SUBSTANCES INSOLUBLE IN WATER AND IN MURIATIC ACID.

The insoluble mass which was left on the filter after treatment with muriatic acid, and which was kept for further examination, remains now to be analysed. Take therefore a certain portion of this insoluble mass, and reduce it into as fine a powder as possible by trituration with water, in an agate mortar. After triturating for some time, water is poured into the mortar, and the whole is stirred; the smallest particles are thus suspended in the water, which should be poured out into a capsule, whilst the coarser particles remain in the water, and must be triturated again. Take 50 or 100 grains of the powder thus obtained, and mix it with four times its weight of dry carbonate of soda in powder. The mixture is effected in a glazed porcelain mortar, and continued until the mass is quite homogeneous—the contents are then emptied upon a sheet of glazed paper, and transferred to the platinum crucible. The platinum crucible should then be exposed to a good fusing heat, for about half an hour.

Where coal-gas is used my gas-furnace will be found exceedingly convenient; it is as follows:—



A is a common argand burner, perforated with eighteen holes.

B is a gallery or support, with four transverse or horizontal arms to support the iron-plate chimney, C.

C is the iron-plate chimney, with a rim at *c′*, on which a disc of wire-gauze, D, is firmly fixed.

D is the disc of wire gauze, having about 700 openings to the square inch.

E is a chimney, which may be fixed to the rim *c′* by small pressing screws, or any other convenient way. It may be made with a crucible, the bottom of which has been neatly removed and smoothed. It might also be made of iron; but I prefer it of pottery, or clay, or china, because these substances, being non-conductors of heat, the whole apparatus remains quite cold, and can be shifted or handled always and at any time pending the operation. This chimney is the reservoir for the mixture of coal-gas and air, to be inflamed at *d′*.

F is a copper pipe having an opening at *d′*, of about one-sixteenth of an inch, screwed by a flange and nut at *f*, and connected by means of a vulcanized or sulphurized caoutchouc or other flexible tube G, with a bladder H, full of air, and pressed between two boards loaded with a weight as represented.

I is a crucible jacket for holding the crucible over the powerful flame of the mixture of coal-gas and air urged by the blowpipe jet, F. The crucible is resting upon knife edges.

The ingenious operator may easily fit to the bladder another flexible tube provided with a valve, for the purpose of reinflating the bladder without disconnecting it or stopping the experiment.

With such an apparatus, carbonate of potash can be fused in a very short space of time.

If, however, a charcoal, or coke fire is used, the furnace should have a good draught, and the platinum crucible should be protected from the action of the fire by placing it into another Hessian or Cornish crucible. The fusion being accomplished, the crucible is withdrawn from the fire, and allowed to cool. If the mass in the crucible is green, or has a greenish blue tinge, it is a sign of the presence of manganese. The crucible, having cooled, should be turned upside down over a glass beaker, and the operator endeavour, by slightly compressing and bending the crucible between the fingers, to detach the mass and make it fall into the beaker. If, however, a portion should remain attached to the crucible it should be softened by water, and as much as possible conveyed to the beaker; but in order to remove the last particles adhering to the crucible, dilute muriatic acid is poured into it, by which they are readily dissolved. The fused mass being now collected in the beaker, water is poured upon it, and then some dilute muriatic acid is added, but with care and by small portions at a time, in order to guard against a strong effervescence, and the beaker should be covered with a concave piece of glass, or with a capsule, in order to prevent loss. When the effervescence, which is always strong, has ceased, and is not reproduced by a fresh quantity of acid, the contents of the beaker are left to digest for some time: whether the insoluble mass has been entirely decomposed by the carbonate of soda, is ascertained by rubbing the bottom and sides of the beaker with a glass rod. If any powder has escaped decomposition, it is immediately discovered by the gritty noise produced, and in that case the supernatant liquor should be carefully decanted, and the insoluble portion fused with a fresh quantity of carbonate of soda.

The acid liquor is evaporated to dryness in the sand-bath, and in a porcelain capsule, along with the silica which has separated. When the liquor has assumed by evaporation a syrupy consistence, the heat applied must be very gentle, otherwise a portion might spirt and be projected out of the crucible, which would of course render the analysis inaccurate. It is advisable also to keep stirring the mass with a glass rod towards the end of the operation, that is, until the mass has decome perfectly dry. After cooling, the mass should be drenched with muriatic acid and left in contact with the acid for about half an hour, and water is then poured upon it. This dissolves everything but the silica, which may then be collected on a filter, washed, dried, exposed to a red heat, and weighed.

The acid solution filtered from the silica is then treated exactly in the same manner as that of the soil which was insoluble in water but soluble in muriatic acid, with this exception only, that, as carbonate of soda has been used, the presence of that alkali cannot of course be estimated.

Estimation of the particular forms of organic matter in the soil.

Take 1000 grains of the soil under examination, boil it for about an hour in water, throw the whole upon a filter, and wash the soil on the filter.

The aqueous solution filtered from the soil should then be evaporated to dryness, and the residuum exposed to a heat of about 240° Fahr. in the oil-bath. The dry residuum is then digested in water, which will dissolve a portion of it. The whole is thrown on a filter; and the insoluble portion, which may consist of *humic*, *ulmic*, and *geic* acids, is kept for further examination.

The liquor filtered from the insoluble humic, ulmic, and geic acids just mentioned, should be evaporated to dryness and weighed. The weight being noted, the residuum is exposed to a red heat until quite reduced to ashes and again weighed, the loss is taken account of as—CRENIC and APOCRENIC ACIDS.

The residuum insoluble in water, which may consist of *humic*, *ulmic*, and *geic* acids, and likewise of *humine*, should be boiled or digested for several hours in a hot solution of carbonate of soda, the liquor is then filtered to separate it from the insoluble portion, and hydrochloric acid is added to the filtered liquor until it begins to redden litmus paper. This saturation with hydrochloric acid precipitates brown pulverulent flakes, which consist of HUMIC, ULMIC, or GEIC acid, or a mixture of all these three acids, which, being collected in a counterpoised filter, washed, and dried at about 230° Fahr., is then weighed. The dried mass is then exposed to a red heat in a platinum crucible, and the ashes left are weighed; the loss is taken account of as—HUMIC, ULMIC, OR GEIC ACID.

The portion which remained insoluble, after digestion with solution of carbonate of soda, should then be boiled for several hours with caustic potash, taking care to replace the water which evaporates; the liquor is then diluted with water, and filtered, the filtered liquor is evaporated to dryness, and weighed; the residuum is then ignited, and the loss is taken account of as—HUMINE.

Another 1000 grains of soil should be exposed in a platinum crucible to a red heat until all the organic matter is completely consumed and reduced to ashes, the mass is then drenched with a solution of carbonate of ammonia; and the mass, being dried, is gradually ignited at a low red heat; it is then weighed. By subtracting the proportions of crenic and apocrenic, humic, geic, and ulmic acids previously found, the difference is taken account of as—UNDECOMPOSED ORGANIC MATTER.

The above organic acids are produced in soils by the decomposition of humus, that is, of the decaying vegetable matter contained in soils. Humic, ulmic, and geic acids have a great affinity for ammonia which they abstract from the atmosphere, and they thus become readily soluble in water; whilst in the free state they are almost insoluble in that liquid, and cannot therefore be taken up as food by plants. The proportion of these acids in arable soils varies from 1 per cent., or even less, to 7 or 8 per cent.; but in peat their amount is considerable. Crenic and apocrenic acids are derived from the acids above named, that is, they are, in fact, the same acids more oxygenized; or rather, all these acids are the results of decayed organic matter, combining gradually with larger and larger proportions of oxygen. Thus says Professor Johnston:—

"The ulmic acid is the first formed from the decay of vegetable matter. Hence, in peat bogs the red turf is usually found nearest to the surface.

"The humic acid is formed from the ulmic by the absorption of more oxygen from the atmosphere. It consists of carbon and water only.

"The geic contains more oxygen than the humic acid, and is formed from it by the absorption of a further quantity of oxygen from the air, or from the water with which it is in contact.

"The crenic and apocrenic acids contain still more oxygen, and, along with other substances produced in the soil, are formed by the union of the geic acid with another proportion of oxygen.

"Thus, decaying vegetable matter appears first to form the ulmic, next the humic, then the geic, after that the crenic and apocrenic acids. We do not know how many other compounds may succeed to these by the union of their elements with more and more oxygen, before they are entirely resolved into carbonic acid,—the final state to which all these changes ultimately lead.

"These successive absorptions of oxygen by the decaying vegetable matter, promote the production of ammonia in the soil, as well as of nitric acid."

CHAPTER VII.

CHEMICAL METHODS OF MAINTAINING, INCREASING, OR RESTORING THE FERTILITY OF SOILS—ON MANURES—VEGETABLE, ANIMAL, AND VEGETO-ANIMAL OR MIXED MANURES—FARM-YARD MANURE—GUANO—COMPOSTS—INORGANIC, SALINE, OR MINERAL MANURES—CLASSIFICATION AND USE OF MANURES.

We said in a former chapter that plants derived their nourishment both from the air and from the soil; that is to say, they take up and absorb both from the air and from the soil, the elements which are necessary to their sustenance, and which becoming assimilated with and fixed in their tissues, are thus transformed into constituent parts of their being. The air, however, is an inexhaustible source of alimentary supplies, but not so the soil, which becomes gradually impoverished at each successive draught that is made upon its stores of saline matters, and which might eventually become so utterly exhausted that nothing, *not even weeds,* could grow upon it. In effect, soils do not contain an unlimited quantity of those salts, and yet without them vegetation languishes, or, as we said, ceases altogether. If therefore plants be injudiciously, carelessly, and closely quartered upon a soil, or if crop after crop is improvidently and greedily gathered, the natural provisions of ammonia, of phosphates, of silicates, of potash, of soda, &c. stored in the soil, will be absorbed, and, as it were, eaten up, and when gone, the plants will become, so to speak, famine-stricken, and will eventually die of starvation, unless the soil be re-victualled by an importation of fresh supplies. It is therefore absolutely necessary to restore to the land what it loses by cropping, in order to enable it to support vegetation at all, but that is not sufficient for the purposes of practical agriculture, the aim of which is to produce the greatest amount of crop of the best possible quality, at least cost, which result may be secured to the fullest extent, on the one hand, by *judiciously* augmenting the proportion of the ingredients or constituents which may naturally exist in a soil suited to particular kinds of plants, by which the fertility of the soil will be increased; and, on the other hand, by putting and maintaining the soil in the best possible condition for the due development of the plants and preparation of their food, by ploughing, &c., and other mechanical field operations which it is not our province to treat of here.

But in order to augment the proportions of any one particular ingredient in the soil which is intended to minister to the wants of any particular plant, of course it is necessary to know what ingredient is particular food for that plant. Hence, the farmer must well consider, by reference to the analyses which have been made of the various plants, what their constituents are, and then what manure will best answer the purpose. And yet he must take care not to feed the plant overmuch by an extravagantly *high farming*, for plants, like animals, may die as much of surfeit as of starvation. The starved plant is slender and weak, meagre, and, so to speak, only skin and bone; the overfed plant, if well watered, or in rainy weather, grows up in stalk and leaves, both of which become exceedingly large, but their tissue or texture is *hollow* and flabby; if, on the contrary, dry weather succeeds after sudden and violent rain, the soluble salts which had been taken up in greater proportion than their organs can bear, become concentrated by the evaporation of the water absorbed by the roots, circulation is stopped or interfered with, it is a case of indigestion, the patient shows its furred leaves covered with a thin white crust, like the tongue of a feverish man, and unless a shower falls in time to dissolve and wash away this efflorescence which stops the pores of the plant and impedes its respiration, it dies, gorged, asphyxiated, smothered.

Although a liberal and judicious use of manures is necessary to maintain the fertility of soils, the farmer should always bear in mind that it is only good lands which may thus be benefited, because a long series of rotations of crops may thus be obtained, which on poor lands, however well and abundantly manured, cannot be carried on, and the product of which is always less abundant, and therefore less remunerative in every way. He should remember that the sterility, or poverty of a soil often depends on its very constitution which no manuring can alter, at least, in a permanent manner, and that the remedy in such cases must therefore be sought, not in an extravagant, because useless, expenditure of manures, but in an admixture of other earths, by which its constitution and texture may be modified; such as, for example, by adding *clay* to *calcareous soils*, or *sand* to *clayey soils*, and *vice versâ*, which implies, of course, a knowledge of the constituents of the soils, for the determination of which we have given the necessary instructions in the preceding chapter.

The fertility of a soil may be maintained or restored in three various ways, namely, by letting the land lie fallow, by rotation of crops, and by manuring. This last process, which is the only chemical one by which fertility can be artificially increased, will alone engage our attention.

Manures are of an ORGANIC or of an INORGANIC nature.

ORGANIC MANURES are either vegetable or animal manures, or mixtures of both vegetable and animal substances.

Vegetable manures are—green crops and sea-weeds, straw, bran, brewers' grains, malt dust, rape cake, rape dust, linseed cake, tanners' bark, &c.

Animal manures consist of the blood and flesh of carcases, hair, woollen rags, bones, urine, night-soil, poudrette, guano, and all fatty or greasy matter.

Mixed or *vegeto-animal manures* are farm yard dungs.

INORGANIC MANURES are saline or mineral manures, such as wood ashes, leys, soot, plaster, sulphate and other salts of ammonia, ammoniacal water, phosphates and superphosphate of lime, common salt, carbonates, nitrates, and silicates of potash and of soda, sulphates of potash, of soda, of lime, and of magnesia, &c.

GREEN MANURES consist in the ploughing in of green crops, if possible, when ripe, for it is at that time that they contain the greatest quantity of soluble matter. The best plants for the purpose are *clover, rape, vetches, lucerne, sainfoin, buck-wheat, borage, cabbage-leaves, radishes, winter tares, Indian corn, potato* and *turnip tops, wild mustard*, &c. Yet the choice among these plants in their application to various soils is not indifferent.

The plants which are most suitable as green manure in clayey soils are:—horse-beans, clover, rape, vetches, lucerne, sainfoin, peas, &c. In light or sandy soils, buck-wheat, white clover, borage, cabbage, radishes, winter tares, rye, wild mustard, Indian corn, corn spurrey, potato and turnip tops, &c., are preferable.

Green manuring is especially applicable to mountainous districts where the expence of carriage for other manure would be too considerable, and also to poor soils deficient in clay, which cannot retain water, and consequently are soon too dry for profitable vegetation. On silicious, arid, and burning soils, green soils, the use of green manures is very beneficial, because they are much more rapidly decomposed than dry manures, they soon supply such soils with vegetable mould, which, being retentive of water, is exceedingly serviceable in times of drought. It is well, however, in such soils to plough in some lime along with the green crops, in order to saturate the organic acids which are produced by their decomposition.

In calcareous soils, green manures are exceedingly advantageous, and they may be ploughed in without any preparation or correction.

Green manures should be ploughed in at a moderate depth; for example, three or four inches.

Wheat is perhaps, of all crops, that which is most benefited by green manures.

On the other hand, green manures should not be applied to very clayey soils, because the result of the decomposition of green crops being to produce certain organic acids, and a mould which is retentive of water, they would render such soils still more moist and cold than they are already; and those soils not containing enough lime, or any lime at all, nor other available gases to saturate the organic acids above alluded to, would possibly be more injured than benefited by the practice. This last objection, however, may be readily guarded against, as was said before, by ploughing in, with the green crop, a sufficient quantity of lime, coal ashes, or road drift.

Sea-weeds contain a good deal of nitrogen, a large proportion of alkaline and earthy salts, and, as they undergo decomposition much more rapidly than other green manures, so their effect on vegetation is proportionally much more powerful, but it is also much less lasting, and, in fact, does not extend beyond one season. Sea-weeds may be ploughed in like other green manures, but this should be done as soon as possible, or if this is not practicable they should be stratified with earth and lime, in order to convert them into a compost, or else they may be mixed with ordinary manure. Sea-weeds act beneficially on all ordinary crops; if spread upon grass in summer or autumn they promote its growth, and a crop of grain subsequently obtained from such a soil is said to be much improved, at least in quantity, for the quality of the corn is said to be somewhat deteriorated by the use of that manure. In the North of Scotland farmers are said to prefer sea-weed to any other manure for cabbages. Sea-weeds form an excellent manure for lint and hemp, the flax obtained being improved thereby, both in quantity and quality. Rye, oats, turnips, and clover are benefited by that manure. About ten cart-loads of sea-weeds are reckoned a sufficient quantity for three acres. The action of sea-weeds as manure upon vegetables is immediate, but does not last more than one season, and consequently a fresh quantity is required for each crop. The action of sea-weeds is so great, owing to the larger quantity of nitrogen which they contain, that one cart-load of them produces as much effect as about four tons of farm-yard manure.

Straw, leaves, bran, &c. Not only are the straw and leaves of vegetables a source of nourishment to plants; the straw and leaves furnished by particular vegetables are the best manure and food for those particular vegetables. According to this principle, wheat straw is an excellent manure for wheat, potato-leaves and stalks for potatoes, &c. In applying straw as manure, however, Mr. John Shier observes, "That the texture of the soil is a very important consideration. Organic matter decays very slowly in stiff clay soils, because of the imperfect admission of air. Straw ploughed in acts beneficially on such soils by increasing their porosity; the admitted air causing decay both of the straw, and of organic matter previously existing in them. Accordingly, it will be found on inquiry, that the cases where dry straw has been beneficially employed were on stiff soils, and where immediate effect was not required or looked for. On porous soils the use of dry straw is contra-indicated, by its tendency to increase an existing evil; and also because such soils have less organic matter in them, and are therefore more dependent on large supplies of rapidly acting manure. As agriculture advances there is always a greater tendency to special manuring; that is to say, to apply manures to more than one crop of a rotation; use being at the same time made of the residuary portions of crops that are not carried off the field; and this practice, except in special cases, rather precludes the employment of dry straw.

"One case there is of ploughing in dry straw, which admits of no debate, namely, that of stubble. With respect to the best method of ploughing in stubbles, little requires to be said. In stiff land, the sooner it is ploughed down the better; both because the fresher the roots, the more rapidly do they decompose, and because the action of the frost opens the soil and admits the air and moisture necessary. On porous soils, however, stubbles are often treated otherwise; the method of *break-furrowing*, as it is termed in Scotland, being had recourse to. The field is ribbed, that is to say, only every alternate furrow-slice is turned, and being laid on the space adjoining it, the stubbles of the very thin turned slice are applied to those of the undisturbed one; where, from free access of air they decompose; while the otherwise too friable soil is not too much disintegrated by frost."

Rape cake, linseed cake, as may be seen in the table on the relative value of manures at the end of this part of the book, contains a pretty large quantity of nitrogen on which their value mainly depends; these cakes are, moreover, beneficially applied to soils which are poor in organic matter, and which require a little moisture. As a top dressing they are said to yield good results both in grain and in straw. They are used also alone for turnips and potatoes, but they act best as a manure for rape, lint, and other plants producing only seeds. Linseed cake being used as fodder for cattle, is rarely, except under peculiar circumstances, employed as manure.

If the agriculturist wishes to obtain immediately the effect of that manure, he should apply it in wet weather. If employed in dry weather, the action will be produced the ensuing year only. Rape and linseed cake give the best results on light sandy soils, especially when reduced into fine powder, and then mixed with as much putrified urine, or water of dunghills, as will form a thickish liquid which may be left to ferment slightly for ten or twelve days, and may then be showered upon the soil with a scoop, or other suitable instrument. It is asserted that the manure under present consideration is fatal to the grub of the cockchafer and to the mole cricket.

Be this as it may, rape or linseed cake should never be bought in the pulverized state, for the obvious reason that in that form there is a very great chance of its being adulterated with all sorts of substances, such as saw-dust, fine earth, or sand, &c.

With respect to the other vegetable manures, they act more or less in the same manner; and what we have said will probably be sufficient to enable the reader, reference being had to the table at the end, to judge of their value and to guide him in their application; Mr. Johnston, in reference to these manures, remarks:—

"That the *immediate* effect of vegetable manures in hastening the growth is dependent, in a great degree, upon the quantity of nitrogen they contain, and give off during their decay in the soil; but that their *permanent* effect and value is to be estimated chiefly by the quantity and quality of the inorganic matter they contain,—of the ash they leave when burnt."

The reader, moreover, will bear in mind, that when green manures are intended to be used on an impoverished soil, it is a *sine quâ non* condition of success to sow in it for the purpose only such plants as take up all the water, carbon, and nitrogen necessary to their growth, more or less exclusively from the atmosphere.

ANIMAL MANURES.—Animal manures are more powerful than either vegetable or mixed manures, this is owing to the enormous quantity of nitrogen and carbon which they contain, and also to the presence of certain salts of great importance, which exist in them to a considerable extent, as will be shown presently.

The *flesh of quadrupeds*, fish, and other dead animals, contains about 50 per cent. of carbon, and from 13 to 17 per cent. of nitrogen, besides salts of potash, of soda, of lime, of magnesia, and is therefore one of the very best manures that can be. These carcasses of dead animals, fish, offal, and all animal refuse should never be applied directly to the soil, but made into a compost. The best and most economical way perhaps of making such a compost, consists in placing the carcass of the animal into a hole excavated in a convenient place for its reception, and sprinkling quick-lime all over it, a layer of earth should then be put over that, and again over that a layer of plaster, then a layer of earth mixed with copperas in small fragments, or, better still, in the pulverized state. The rest of the earth obtained from the excavation should then be heaped up on the mass so as to form a small hillock. In about a fortnight the decomposition of the carcass is effected. The mixture may then be dug up, the bones are separated, and subsequently employed as bone manure as will be described presently, and the rest of the mass, after being mixed with five or six times its weight of fine earth is kept for about a fortnight, stirring and digging it up from time to time, in order to mix the whole mass thoroughly, and it is then ready for use. The sulphate of lime (plaster,) and the sulphate of iron (copperas), are employed in this compost for the purpose of absorbing and fixing the ammoniacal emanations which are thus converted into sulphate of ammonia; whilst, at the same time, the sulphuretted hydrogen being, in the present instance, decomposed by the copperas, all unpleasant effluvia are avoided.

When dead fish or fish refuse is strewn upon land, as is sometimes done, it almost invariably imparts a disagreeable, fishy flavour, not only to the crop, but likewise to the butter and to the milk of the cattle who feed upon such crops.

Hoofs, hairs, feathers, skins, wool, contain more than 50 per cent. of carbon, and from 13 to 18 per cent. of nitrogen, besides sulphur, salts of lime, of soda, and of magnesia.

These substances hold therefore the first rank, as it were, amongst manures, and, as a long time is required for their decomposition, their action may often last for seven or eight years. They yield excellent results, especially when made into a compost for potatoes, turnips, hops, hay, and generally on meadow land.

Hairs spread upon meadows are said to augment the crop threefold; and the Chinese, we are told, are so well aware of the very great value of that manure, that they carefully collect the hair every time they have their head shaved, (and the operation is performed every fortnight,) and sell it to their farmers. Now the crop of hair which every individual leaves at the hair-cutter's yearly, amounts to about half-a-pound; reckoning therefore at thirteen millions, the number of individuals who in Great Britain and Ireland are undergoing the process of shaving and hair-cutting, we have a production of about three thousand tons of hair, that is of manure of the most valuable kind, (since it represents at least 150 thousand tons of ordinary farm-yard manure,) which might be collected almost without trouble, but which on the contrary, such is, our carelessness or indolence in those matters, is, I believe, invariable swept away in our streets or sewers and utterly wasted.

Blood contains more than 52 per cent. of carbon, more than 17 per cent. of nitrogen, soluble salts, such as a large quantity of common salt, phosphates, sulphates, and carbonates of soda, of potash, &c., and some insoluble salts, namely, phosphate of lime, and of magnesia, &c.

Blood, like flesh, is generally made into a compost with other substances; on light soils such a compost produces excellent crops, whilst on clayey soils it scarcely has any effect at all.

Bones contain more than 7 per cent. of nitrogen, and likewise more than 53 per cent. of phosphate of lime, a little phosphate of magnesia, carbonate of soda, &c. The large proportion of phosphates renders this manure particularly advantageous, (especially when converted into perphosphates,) for the growth of a great number of vegetables, especially the cereales and leguminous plants, because it is the phosphates which are removed to the greatest extent by the reaping of successive crops, and by the feeding of cattle. It is from the presence of phosphates that bones derive their principal, though not their only value, since the fat which they contain and their cellular tissue, are the source of a pretty large quantity of carbonate and other salts of ammonia. Like horn, hoofs, feathers, &c., bones require a long time for their decomposition, and their useful effect is very lasting in consequence. This decomposition is much accelerated by pulverizing the bones, and it is in fact in this form that they are generally used, and in the proportion of about 10 or 12 cwts. per acre.

Bones, however, are far from having a uniform value, and if bought in the state of bone-dust, there is much danger of adulteration, either with worthless or almost worthless materials, or of admixture with bones of an inferior quality, in this way:—in various establishments, principally at glue or size makers, bones are boiled for the sake of their fat and of their gelatine, and the bones thus deprived of these constituents are then sold or mixed with *green bones* which have intrinsically a greater value, since boiled bones are valuable only on account of their phosphates, whilst green bones contain besides 33 per cent. at least of cellular and other tissues which may yield from 5 to 7 per cent. of nitrogen.

We said just now that the decomposition of bones was much accelerated by pulverizing, but their action on lands may be rendered as rapid as that of the most soluble saline manures, by converting their phosphates into perphosphates, which is done by mixing the bone-dust with half its weight of sulphuric acid, previously diluted with about three times its bulk of water. The whole is then thoroughly and carefully mixed by means of wooden shovels, and left at rest for about twenty-four hours. The mass, which has a pasty consistence, is diluted with 100 times as much water as was used in the first instance to dilute the sulphuric acid, and it may then be sprinkled on the field by means of scoops or of the water-cart; or, instead of water, a suitable quantity of charcoal powder, or of soot, or of saw-dust, or even of fine earth, is added so as to render the pasty mass sufficiently dry to be comfortably handled.

The only way of ascertaining the value of bone-dust is by determining the amount of nitrogen and of phosphoric acid which it contains. The methods of doing this are the same as described in the analysis of guano.

Excrements are either solid or liquid—they comprise night-soil, poudrette, colombine, poultry-dung, guano, sheep's dung, &c., and the urine of various animals. Excrements contain a large proportion of nitrogen, of earthy and alkaline salts, which render them exceedingly valuable as manures.

Of all animal manures night-soil is perhaps the most powerful and efficacious, the richest and the best, as may be seen from the following analysis.

According to Bezelius, 100 parts of fœces contain:—

Water		73·3
Bile	0·9	5·7
Albumen	0·9	
Peculiar extractive matter	2·7	
Salts	1·2	
Organic detritus		7·0
Insoluble matters, mucus, biliary-resin, fat, peculiar animal matter		14·0
		100·0

According to Fleitmann, the following are the inorganic constituents of the fœces:—

Chloride of potassium	0·07
Chloride of sodium (common salt)	0·58
Tribasic phosphate of potash	14·70
Do. phosphate of soda	1·32
Do. phosphate of lime	37·95
Do. phosphate of magnesia	15·36
Sulphate of potash	0·63
Silicate of potash	0·20
Sulphate of lime (plaster)	1·43
Silicate of lime	0·23
Carbonate of potash	3·28
Hydrate of potash	10·05
Silicate of iron?	3·28
Magnesia	3·53
Sand	7·39
	100·00

These analyses show that night-soil contains in a concentrated form all the organic and saline substances necessary to the development of plants; the disgusting nature of that substance however, its fetor, the difficulty and loathsomeness attending its collection, and the physical evils resulting from cess-pools, the unhealthiness of the effluvia which arise from the accumulation of filth in such receptacles, are the chief objections to the use of night-soil, and have led to the adoption, at least in many towns, of a vast system of sewage for the, as was contemplated, speedy and complete removal of this foul refuse. But as these sewers have been so contrived as to discharge themselves in the neighbouring rivers from which a great number of the community obtain their daily supply of water, as is the case in London, in the district of Westminster for example, and as the drainage is far from being perfect, the most fœtid and nauseous exhalations are perpetually evolved at every grating of these dark subterraneous channels, and through every pipe which connects the cesspools or drains of every house with them. It is certain that the enormous expenditure of perhaps two millions sterling, sunk in the construction of the London sewers, and the sacrifice or waste of at least one million sterling per annum, which the sale of the London night-soil would realize if collected, far from ministering to the comforts of the inhabitants, promotes disease and shortens their lives, for it is by no means improbable that the putrid animal and vegetable refuse thus spread by means of the sewers over an excessively large space, does more mischief than when accumulated in larger masses. I beg to reproduce here a quotation made in my Commercial Hand Book of Chemical Analysis, page 583, from one of "Chambers' Papers for the People," entitled "Sanitary Movement," which deserves the most serious meditation.

"London is supplied with water by eight principal companies, and two or three minor ones, who furnish, according to Mr. Fletcher's calculation, as read before the Statistical Society, 330,000,000 hogsheads yearly; being 10,140,500 cubic feet per day, or at the rate of 30 gallons for each individual of the population. Yet it is notorious that there are in London 70,000 houses, occupied by more than half a million of inhabitants, which have no supply whatever. It is in this class of dwellings that the miserable make-shifts take place alluded to above, as exhibited most markedly in the east of London, where some hundreds of 'stand-cocks,' scattered over the 'low neighbourhoods,' with an intermittent supply, afford but scanty means for comfort or cleanliness.

"The thirty gallons per day to each individual is thus shown to be practically a fallacy. Yet were it true, certain essentials would still be lacking. We want water, but good water, sweet and wholesome — not diluted mud or sewer refuse. The Thames, in its course of 160 miles, receives the refuse outpourings of 223 cities, towns, and villages; the metropolis discharges its pestilential tribute to the noble river through 130 sewers, to the amount of 30,000,000 gallons daily, or 130,000 tons. Among a population of 2,000,000, the mere daily ablutions must contribute largely to the causes of contamination; add to this the excrementitious matters, the washings of foul linen, the filth and refuse of many hundred manufactories, the offal and decomposing vegetable substances from the markets, the foul and gory liquid from slaughter-houses, and the purulent abominations from hospitals and dissecting-rooms, and an idea may be formed of the quality of the fluid which no inconsiderable portion of the inhabitants of London are doomed to drink, to use for all domestic purposes every day of their lives, unless, indeed, they abjure the impure element altogether, and consume it as disguised by brewers, distillers, and licensed victuallers.

" The Lambeth Company, which distributes water over a large part of the low, flat district on the south of the Thames, take their supply from the river near to Charing Cross Suspension Bridge; they pump it at once, without any intermediate process of filtration, into the cisterns of their customers. Now, it is worthy of remark, that during the late visitation of cholera, the deaths were more numerous on the Lambeth side of the river than in any other part. The maximum mortality fell in Rotherhithe, a district supplied with water from the Thames, near Chelsea Hospital. The whole of this peninsulated region lies low, as before stated, some feet below high-water mark—a fact not to be lost sight of in theorizing on the relation between impure water and choleraic phenomena. But when we find the more elevated districts—supplied by the New River, and the companies deriving their supplies from Hampstead and from the Thames at Kew and Hammersmith, sources of *comparative* purity—escaping almost intact, we cannot resist the inference that bad water induces an abnormal condition in those who drink it favourable to the encroachments of disease. From time to time, a panic has seized the public mind on the subject of Thames water; and companies have filtered on a large, and individuals on a small scale, hoping to obtain a drinkable beverage. In 1828, a committee of medical and scientific gentlemen appointed by Parliament drew up a report on the water question. We have quoted from this report above. As regards the mechanical cleansing, they considered it obvious, that water receiving so large a proportion of foreign matters as we know find their way into the Thames, and so far impure as to destroy fish, cannot, even when clarified by filtration, be pronounced entirely free from the suspicion of general insalubrity. Analyses of water engaged the attention of Berzelius during some of the latter years of his life: that great chemist found it impossible to divest water, once contaminated by human excretæ, of its noxious principles."

To render the sewage of large towns available for the purposes of agriculture is an extremely difficult problem, and one which unfortunately is not likely to receive a speedy solution. But considering that night-soil can be easily disinfected, by pouring upon it solutions of various metallic salts, which can be procured at an exceedingly low price, such as green copperas, chloride of manganese, sulphate and chloride of zinc, the attention of the public in general, cannot be too earnestly called to the importance of such operations as capable of securing an enormous and always productive source of wealth, now suffered not only to be wasted, but to vitiate the air we breathe, to poison the water we drink, and in every way to put our purse, our health, and our lives in jeopardy.

Poudrette is produced by drying the solid and liquid excrements of large cities. It is principally manufactured on the continent, and forms a considerable branch of exportation. It is a very powerful manure, but is far from containing all the valuable elements of the night-soil from which it is obtained. It is a brown powder with a slight musky odour, moist and greasy to the touch, and which may be agglomerated by pressing it in the hands. The composition of the Parisian poudrette is as follows:—

Water	52·5
Ammoniacal salts	3·9
Nitrogenized organic matter	18·1
Fixed mineral substances	25·5
	100·0

In spite of the loss of the valuable constituents which night-soil suffers in the process of conversion into poudrette, the latter substance is still equivalent to about thirty times its bulk of farm-yard manure. It is asserted, however, by some agriculturalists, though stoutly denied by others, that its use imparts to plants a disagreeable taste. Be this as it may, it is an additional reason why the night-soil itself should be disinfected as above mentioned, and then it might be mixed with soot or other absorbing materials.

URINE.—The urine of all animals is a very powerful manure, the action of which on vegetation is very rapid. It contains sulphates of potash and of soda, common salt, lactates and phosphates of potash, of soda, and of ammonia, and a substance exceedingly rich in nitrogen, called *urea*, which is the cause of its rapid putrefactive fermentation; but the amount of these constituents varies, of course, with every kind of animal, its food, &c., &c.

As during the putrefying fermentation, the urea and other substances containing nitrogen (such as the mucus and other animal substances contained in the urine) are converted into carbonate of ammonia, which volatilizes in the air, and as every pound weight of ammonia thus wasted by evaporation, represents a loss of about thirty pounds of corn, and as each pound weight of urine contains as much nitrogen as is sufficient to produce one pound weight of corn, it is evident that the farmer cannot too sedulously collect the urine of his cattle and of all the people on his farm, and prevent the dispersion of the ammonia on which the efficacy of the liquid almost entirely depends. The ammonia of urine may be arrested by mixing with the latter a certain quantity of plaster, of copperas, of Glauber salt, of sulphuric acid, or, better still, of Epsom salts, which produces a precipitate of double phosphate of magnesia and ammonia. The proportions of the above salts, which it is necessary to add to each imperial gallon of urine, are :—

From 30 to 40 grains of plaster,
„ 25 „ 30 „ of copperas,
„ 30 „ 40 „ of Glauber salt,
„ 10 „ 12 „ of oil of vitriol,
„ 25 „ 30 „ of Epsom salts.

[Plaster is less applicable than the other substances here mentioned, because, as it is only sparingly soluble in water, it forms at the bottom of the tank or vessel, a magma which is more troublesome to remove.]

Urine is particularly applicable to sandy or calcareous soils.

Guano is a manure consisting almost entirely of the excrements of sea-birds, and the composition of which is extremely complicated. Its use in Europe began about ten years ago, and as it is the object of numerous and extensive adulterations, we have devoted a separate chapter further on to its examination.

Mixed manures consist of mixtures of animal and of vegetable substances, such as farm-yard dungs, which consist of the excrements of animals, &c., mixed with straw and other vegetable detritus. Yet all farm-yard dung has not the same composition. Thus, the dung of a horse, fed upon dry fodder and oats, contains more nitrogen and less water than that of any other animal, and is more rapidly decomposed; whilst that of the cow contains much less nitrogen and takes a longer time to putrefy; and that of the sheep partakes of both qualities. From this we may readily conceive, that since each kind of farm-yard manure is possessed of peculiar properties, so is each of them applicable to different species of soils, and that each should therefore be kept separate, to be used or mixed as occasion may require, instead of being all promiscuously thrown together into a single mass, as is generally done, and carted away and spread unintelligently upon the soil whatever its nature or constitution may be. Composts belong to the class of mixed manures.

Farm-yard manure should not only be carefully collected, but the manner in which it is collected and kept has a very great influence on its value. If it be left exposed to the air, and suffered to be drenched by rain, or parched up by the sun, a great quantity of the products of its decomposition will be volatilized or washed away. It is, therefore, advisable to keep that kind of manure under a shed, or at any rate leaning against the north side of a wall or building, and, the liquor which percolates should be led, by means of a drain, into a closed receptacle or tank. The temperature of the dunghill should not be permitted to exceed 100° Fahrenheit, and if a smell of ammonia is perceived, or if, on holding a piece of paper moistened with somewhat dilute muriatic acid over the dung or the tank above alluded to, white fumes are observed, it is a proof that the dung, or rather the valuable products of its decomposition are wasting, and means must be immediately employed to fix them, and thus prevent their loss, which may be done by watering it with dilute sulphuric or muriatic acid, or solution of sulphate of iron (copperas), or by sprinkling plaster over it, when the odour of ammonia will immediately disappear.

We said just now, that each kind of farm-yard manure was possessed of peculiar properties, and we adverted to the policy of keeping each separate. In effect the dung of the horned cattle, of the horse, of the sheep, and of the pig, not only vary considerably in the amount of organic matter, and consequently, in the amount of nitrogen which they can produce, but the texture of each of these dungs influences considerably its mode of action. Thus, for example, the dung of the cow being more porous, and consisting of particles in a greater state of division than that of the horse, or of the sheep, does not ferment, and consequently does not act so rapidly, and, as it is more porous, it is more hygrometric, that is, it absorbs more readily and in greater quantity, the aqueous vapours of the air, and, consequently, it keeps the soil in a more moist condition. Cow-dung is, therefore, singularly applicable to calcareous soils, or where droughts prevail; but to employ it upon clayey, or moist, or upon what is called a cold soil, is an irrational practice, whilst upon such soils horse-dung produces the best results. On clayey and moist soils, sheep's dung, though not so efficacious as that of the horse, is very beneficial, and though its action is less rapid, it lasts for a longer period. It is best fitted for meadow lands, as it often imparts an unpleasant flavour to culinary vegetables, and it is asserted that the barley grown on lands manured with it contains less starch, and produces less malt than otherwise would be the case.

Pigs' dung, being very soft, or even liquid, has the same properties as that of the cow, but is best suited to meadow lands, because, like the manure produced by the sheep, it communicates a disagreeable flavour to vegetables.

COMPOSTS belong to the class of mixed manures; that is to say, they consist chiefly of vegetable and of animal substances. Composts are economical manures, made of all manner of refuse, and which enable the agriculturist to turn to account a vast quantity of matter which otherwise is suffered to be wasted. Composts cannot supersede the use of farm-yard manure, but are precious adjuncts. Although they may be used for arable lands it is better to employ them for meadows, and to reserve the manures for corn and other more valuable crops. Scarcely any matter can come amiss to a compost, the sweepings of houses, the contents of the dust-bin, soap-suds, kitchen refuse, dish-water, urine, excrements, rotten vegetables, weeds, dregs, road-drift, old plaster, scories of smelting furnaces, coal and coke dust, soot, and all sorts of rubbish, and offal, &c.; all can be turned to account, if only gathered and well managed. We give here a certain number of recipes for making composts, which may perhaps be found useful.

Mr. Fleming's peat compost:—

Saw-dust or moss earth	40	bushels.
Coal-tar	20	gallons.
Bone-dust	7	bushels.
Sulphate of soda	1	cwt.
Sulphate of magnesia (Epsom salts) .	1½	cwt.
Common salt	1½	cwt.
Quick-lime	20	bushels.

Mix these materials together into a heap, and leave it to ferment for three weeks, turn the whole over, and again leave it to ferment, when the compost is ready for use. For hay and turnips, this compost, used at the rate of 40 bushels and 64 bushels per acre, is said to answer better even than guano.

For natural or artificial meadow land, the following composts are recommended:—

Make a layer of calcareous earth six or eight inches thick, and strew upon it hay-loft sweepings and weeds, a few handfuls of pulverized plaster. Cover the whole with a second layer of earth, and again strew upon this second layer sweepings of hay, weeds, and plaster, and so on until a heap five or six feet high is formed. Perforate the mass from the top downwards with a pointed stick here and there, so as to make a certain number of holes, and water it copiously with the liquid that drains from the farm-yard manure, with kitchen water, soap-suds, &c. This at the end of two or three months will make an excellent compost, which may be spread on the land as a top-dressing, with great advantage.

Another compost:—

Put road-drift, pulverized bricks or tiles, weeds, and every kind of rotten or decayed fruit, wood-ashes, soot, pigs' dung, in alternate layers, and water the whole with soap-suds and other greasy water, or liquor of farm-yard manure.

Compost for wheat and other cereales:

Road-drift, coal or coke ashes, house-sweepings, pulverized bricks, rubbish, offal, and urine mixed together. This compost applied on clayey compact soils is said to be attended with excellent results.

Road-drift, turf, the mud of ditches and of ponds, fine river sand, or scories from smelting furnaces, cow-dung and straw, nitrate of soda, or of potash, wood-ashes or soap-suds, weeds, rotten wood and leaves mixed together, form an excellent compost for light calcareous or chalky soils.

Composts for turnips, cabbage, mustard, cress, rape, and other *cruciferæ*:—

Road-drift, mud of ponds or ditches, cabbage-stalks and leaves, offal, lime, woollen-rags, plaster, excrements, and water with urine, soap-suds, and the liquor of farm-yard manure; the whole should be allowed to ferment for three or four months.

INORGANIC MANURES.

The inorganic substances generally employed as manures are the following: ammoniacal salts and soot, alkaline carbonates and ashes—common salt (chloride of sodium)—Glauber salt (sulphate of soda)—Epsom salt (sulphate of magnesia)—plaster or gypsum (sulphate of lime) copperas (sulphate of iron)—nitre or saltpetre (nitrate of potash)—nitrate of soda, &c.

Although these mineral substances are elements of food for plants, they must not be considered exclusively in that light, neither must their chemical effect upon the soil be lost sight of; that is to say, the agriculturist must recollect that these saline manures, by meeting in the soil with substances on which they may have a chemical action, they may become decomposed thereby, and a new compound be left in the soil. Such is the effect, for example, of sulphate of soda upon chalk, which produces sulphate of lime. But besides this nutritive and chemical effect, they have a very important action, namely, that of enabling the leaves (more especially) of plants to decompose the carbonic acid of the air with more energy than they otherwise would, and to fix and arrest the carbon thereof. Saline manures likewise increase the vitality of plants, since it has been observed that those which grow on soils on which such manures have been employed resist better the influences of draughts and of changes of temperature. Saline manures of themselves retard the ripening of plants by increasing the development of their leaves, and exposure to the sun's rays is necessary to their action; for in shaded places, and also when used in too large quantities, they are altogether detrimental to vegetation.

However useful saline manures may be in the dietary of plants, they must not be understood as being at any time capable of superseding the necessity of supplying nitrogen to the soil in some way or other, either by organic manures, or by ammoniacal salts; for the crops on a field diminish and increase, not really, as was once stated by an illustrious chemist, in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure, but likewise in proportion to the care which the agriculturist takes of restoring to the land certain substances which animals and crops have removed from it, and which obtained abundantly enough from the atmosphere by uncultivated plants, cannot be supplied from that source in sufficient quantity to meet the wants of the increased production which it is the object of agriculture to promote. In order to obtain a favourable result from the use of saline substances the proportion of organic manure must not be diminished in the slightest degree, that is to say, although the discreet use of saline manures has the most beneficial effect upon our soils,—and though the possibilities of thus augmenting the quantity and quality of our crops is beyond all question,—we repeat it again and again,—it is only when the other conditions, all the other conditions of a good system of culture, have been fulfilled, that these benefits can be realized; and amongst these necessary and indispensable conditions, the proper use of organic manures holds the first place.

Ammonia, as we said, is always one of the most important products of the decomposition of animal bodies, and of all solid or liquid substances derived from that source: ammonia is also produced, but less rapidly, by the decay of vegetable matter in the soil; it is, therefore, only in certain conditions, to a certain extent, and for particular purposes, that ammoniacal salts can be used with advantage;—they cannot altogether replace the farm-yard manure.

Ammoniacal salts, *sal ammoniac*, and *nitrate of ammonia*, are always dear, especially the latter; but *sulphate of ammonia*, which is now extensively manufactured from gas liquor, is a much more come-at-able article: *sulphate of ammonia* is said to be more efficient than sal ammoniac, but less so than the nitrate of that base.

The salts of ammonia are particularly applicable to soils which are rich in phosphates, or which contain a large proportion of those organic acids of which we have been speaking before, namely, *humic*, *ulmic*, and *geic acids*, or which contain much *humine* and *ulmine*, or undecomposed vegetable detritus. Mr. Schattenman says that ammoniacal salts, which are so efficacious when applied to the growth of wheat and of meadow hay, are altogether inert on clover and lucerne. The truth of this assertion, however, is very questionable, since many agriculturists do affirm, that the use of ammoniacal salts is as beneficial upon these plants as on any other. This discrepancy on a matter of fact may be explained and cleared up in the following manner:—

According to Boussingault, it would appear that carbonate of ammonia is the only beneficial salt of that substance, and that all the others, that is, the sulphate, the muriate, the phosphate of ammonia, act as poisons on vegetation. But when these latter salts are spread upon a soil, they are eventually converted by double decomposition into carbonate of ammonia, and sulphate, phosphate, or muriate of lime, that is, provided the soil contains carbonate of lime (chalk), and provided, also, a certain degree of moisture be present. This last condition of moisture is not less important than the presence of chalk in the soil. For if there be too much water, the decomposition of the ammoniacal salts, and their conversion into carbonate of ammonia, does not take place, although the soil may contain an abundance of chalk. This may be experimentally proved as follows:—

Triturate together, in a perfectly dry mortar, some chalk and some sulphate of ammonia, both perfectly dry; no ammonia, or rather carbonate of ammonia, will be liberated, or at any rate only traces of it will be evolved. But let the whole be exposed for some time to the air, or add a few drops of water to the mass, copious fumes of ammonia, recognizable by their odour, will be instantly given off. Drench the whole with water, and the evolution of ammonia instantly ceases.

From this we may conclude, that since the presence of chalk, and of a certain degree of moisture, are necessary to decompose the ammoniacal salts employed, and convert them into carbonate of ammonia, the failures mentioned by Schattenman may be referred either to the absence of chalk, or to a superabundance of moisture in the soils on which he operated.

In purchasing this salt, that which contains iron should be rejected. When sulphate of ammonia contains much iron, it has a reddish brown, or else a greenish colour, turning reddish brown by exposure. The presence of iron in sulphate of ammonia can be immediately detected by dissolving a small portion of the salt in water, and then adding a drop of hydrosulphuret of ammonia, which will produce a brownish black colour if only a trace of iron is present, but a black precipitate if it contains a more considerable quantity of iron. The proportion of iron in sulphate of ammonia may be easily estimated by dissolving a known weight of the salt in water, acidifying it with nitric acid, boiling the whole, and, when cold, adding an excess of ammonia, which will precipitate the iron in reddish brown flakes, which may be collected on a filter, washed, dried, exposed to a red heat in a platinum crucible, and weighed. Iron may thus be detected and estimated in all the salts of ammonia.

Sulphate of ammonia is often adulterated with sulphate of soda, which is not one-fourth of its value; this fraud is easily detected, because, as sulphate of ammonia is volatile, whilst sulphate of soda is fixed, it is sufficient to put a small quantity of the suspected sulphate into a platinum crucible, and to expose it therein for some time to a low red heat, stirring the mass all the while until vapours cease to be evolved; the sulphate of soda will be left as a fixed residuum. The heat should be applied cautiously, to prevent spirting.

The action of ammoniacal salts upon vegetables is immediate, but does not last more than one season, consequently a fresh quantity is required for each crop.

Nitrate of potash or of soda. Like ammoniacal salts, nitrate of potash or of soda yield nitrogen to plants. The crops most benefited by its use are wheat, and especially barley, provided the soil contains a sufficient proportion of phosphates and of organic matter; and, like ammoniacal salts, it has scarcely any action upon clover.

Nitrate of soda contains, sometimes, very large proportions of common salt. The methods of ascertaining the commercial value of these and other nitrates have been fully explained in my "Commercial Hand-Book of Chemical Analysis," to which the reader is referred.*

Carbonate of potash and of soda.—Wood ashes and leys act nearly in the same way, except that the salt of potash is more valuable; but the value of both depending chiefly upon the quantity of alkali which they contain, that quantity should be estimated, which is done by alkalimetrical operations, which are fully described in my "Guide to Alkalimetry," to which the reader is referred.† The carbonates of alkalies, when much diluted, are extremely beneficial to the growth of clover, meadow hay, and strawberries.

Common salt.—If a certain quantity of sand be mixed with pulverized chalk (carbonate of lime), and if, after moistening the mass with an aqueous solution of common salt (chloride of sodium and muriate of soda), the whole be left exposed to the air, in a sheltered place, in the course of a few weeks an efflorescence will be observed, which, on examination, will be found to consist of carbonate of soda, the chalk becoming at the same time converted into chloride of calcium or muriate of lime; it is, therefore, to the gradual transformation of common salt into carbonate of soda, that the fertilizing effects of that substance should probably be referred; and since this transformation is due to the action of the chalk and the salt upon each other, it is evident, that if the first of these substances is not contained in a sufficient quantity in the soil, or is altogether absent, the addition of salt thereto will, as a consequence, yield but trifling results, or no results at all.

On the other hand, if the soil does not possess, or has not acquired a sufficient degree of moisture, the addition of salt thereto may prove not only useless but hurtful, for without moisture, the decomposition of which we have just been speaking, cannot take place, and it then acts upon the plants, if in sufficient quantity, as a destructive agent.

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* Commercial Hand Book of Chemical Analysis, published by G. Knight and Sons.

† Guide to the Alkalimetrical Chest, or Practical Instructions for the determination of the Commercial Value of Alkalies and of Acids.—London, published by G. Knight and Sons, price 2s.

When mixed, in moderate proportions, with farm-yard manure, or with composts, salt has a most beneficial effect; for, instead of acting as an antiseptic, it then promotes, on the contrary, the putrefactive fermentation of the straw, weeds, and other vegetable or organic detritus, and augments their fertilizing power.

The salt, which has served to the curing of cod and other fish should always be preferred; first, because it is much cheaper, the odour and flavour communicated to it by the organic matter with which it is impregnated rendering it fit only for manufacturing purposes; and, secondly, because the very presence of these organic particles renders it more valuable as a manuring agent.

Plaster—gypsum (sulphate of lime).—For the use and effects of plaster as a manure the reader is referred to what I have already said, page 34. I shall now add here a few words of caution. Pulverized plaster is very often adulterated with pulverized chalk, sand, clay, or marl; therefore, if on pouring a little muriatic acid upon a portion of the plaster an effervescence is produced, it is a proof that it contains a carbonate, probably chalk. Muriatic acid (somewhat diluted) should dissolve it; if a residue is left it is clay, or sand, or both. If, on pouring water upon it, a piece of reddened litmus paper turns blue when moistened with it, the presence of caustic lime is probable. The methods of identifying these substances have been described before, (see page 25 to 37.)

Plaster acts better upon clayey, calcareous, sandy, and loamy soils, than on any other, especially when mixed up with farm-yard manure.

Glauber's salt, (sulphate of soda.)—This salt is said to produce good results with clover and other green crops; it is used in the proportion of 1½cwt. per acre, mixed with other manure.

Epsom salts—(sulphate of magnesia), are employed also for clover and other green crops, and likewise for corn and potato crops, and as a top-dressing for young wheat, especially in soils deficient in magnesia.

The use of sulphate of iron and of the phosphates has been alluded to, page 36, 37, to which the reader is referred.

CHAPTER VIII.

ANALYSIS OF MANURES—OF GUANO—RELATIVE VALUE OF MANURES.

THE only manures which the agriculturist is sure of obtaining in a genuine state are his own farm-yard manures, his own composts, or his own mixtures; all other manures, being the object of regular manufactures, or trades, are liable to be adulterated to a greater or less extent. It is to this latter cause, doubtless, that many cases of failure may frequently be referred, and it is therefore of the utmost importance to the farmer to be able to ascertain whether the constituents which should be present in such manures are really there, and to what extent.

Of all these manures, the composition of guano is the most complicated; we have therefore taken that substance as an example, and indicated the method of analyzing it. By referring to the instructions given it will not be difficult for the operator to apply the same process to the analysis of other manures, or of any of their particular constituents which he may wish to estimate. The two principal ingredients, the amount of which it is important to determine, are nitrogen or ammonia, and the phosphates. Reference to the table at the end of this chapter, will show whether the quantity of nitrogen found is what it should be.

Guano is the Peruvian name of the droppings of sea-fowls, which are now dug out for exportation as a substitute or an adjunct to farm-yard manure.

Guano is a very complex compound, the most important constituents of which consist of phosphates of the earths and of the alkalies, ammonia or ammoniacal salts, or compounds capable of being resolved into ammonia. Guano contains likewise sulphates and chlorides of alkalies, which have also a fertilizing power to a certain extent, but which are of considerably less value in this respect than the other constituents just alluded to.

Liebig, in his work on "*Chemistry, in its Application to Agriculture and Physiology*," quotes the following analysis of guano by Bartels and Volckl.

	Sample from Liverpool.	Sample from Lima.
1. Muriate of ammonia	6·500	4·2
2. Oxalate of ammonia	13·351	10·6
3. Urate of ammonia	3·244	9·0
4. Phosphate of ammonia	6·250	6·0
5. Waxy substance	0·600	"
6. Sulphate of potash	4·227	5·5
7. Sulphate of soda	1·119	3·8
8. Phosphate of soda	5·291	"
9. Phosphate of magnesia and ammonia	4·196	2·6
10. Chloride of sodium	0·100	"
11. Phosphate of lime	9·940	14·3
12. Oxalate of lime	16·360	7·0
13. Alumina	0·104	"
14. Residuum insoluble in nitric acid	5·800	4·7
15. Loss, consisting of water, ammonia, and organic matter not estimated	22·718	3·3
	100·000	100·0

The following analysis of a sample of guano from Bolivia is given by Dr. Ure as a type of that substance in the best state, (Supplement to Dr. Ure's "*Dictionary of Arts, Manufactures, and Mines.*)

SOLUBLE MATTER.

1. Urea	5·00
2. Sulphate of potash	7·90
3. Chloride of sodium	5·00
4. Biphosphate of ammonia	5·50
5. Oxalate of ammonia	0·60
	24·00

INSOLUBLE MATTER.

1. Silica	2·25
2. Subphosphate of lime	9·00
3. Phosphate of magnesia and ammonia	1·25
4. Urate of ammonia	15·27
5. Undefined azotized organic matter, affording with the 14 parts of uric acid by ignition with hydrates of soda, 17.05 parts of ammonia	41·73
	69·50

The mean specific gravity of that sample was 1·63.

"In consequence of the high price of guano," says Mr. Johnston,* "the great demand for it, and the ease with which the unwary farmer may be imposed upon, guano has been frequently adulterated with various substances, and to a great extent. Impositions even have been practised, by selling as genuine guano, artificial mixtures, made to look so like guano that the practical man in remote districts is unable to detect it. A sample of such pretended guano, which had been sold in the neighbourhood of Wigtown, and had been found to produce no effect upon the crops, was lately examined in my laboratory, and found to contain, in the state in which it was sold, more than half its weight of gypsum, the rest being peat or coal ashes, with a little common salt, sulphate of ammonia, and either dried urine, or the refuse of the glue manufactories, to give it a smell. I could not satisfy myself that it contained a particle of real guano. This shows how important it is, that the farmer should possess some means of readily, and at a cheap rate, testing the costly manures he employs." And Mr. Johnston adds in a note:—" Four vessels recently sailed hence for guano stations, ballasted with gypsum, or plaster of Paris. This substance is intended for admixture with guano, and will enable the parties to deliver from the vessel, a nice-looking, and light-coloured article. Parties purchasing guano are very desirous of having it delivered from the vessel, as they believe they obtain it pure. The favourite material for the adulteration of guano, at the present moment, is umber, which is brought from Anglesea, in large quantities. The rate of admixture, we are informed, is about 15 cwts. of umber to about 5 cwts. of Peruvian guano, from which an excellent looking article, called African guano, is manufactured."—*Liverpool Paper.*

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* Elements of Agricultural Chemistry and Geology, by James F. W. Johnston. Published by W. Blackwood and Sons.

In order, however, to ascertain the real value of guano as a fertilizing agent, it is not necessary to perform so elaborate an analysis as those above quoted, and to determine the nature and quantity of all its constituents; for such a purpose it suffices to determine in the sample:—

1st.—The proportion of water. 2nd.—The proportion of fixed alkaline salts. 3rd.—The proportion of sand or of earthy salts. 4th.—The proportion of ammonia, either in the free state or in the state of ammoniacal salts; also the proportion of ammonia which may be produced from the decomposition of the uric and ulmic acids and of other nitrogenized matter present in the guano.

FIRST OPERATION.

100 grains of the sample of guano are weighed off and placed in a counterpoised paper-filter. Concentrated sulphuric acid is then poured into a jar, and the filter containing the guano is suspended over the surface of the acid, by means of threads fastened to a cork with which the jar must be closed air-tight, until the guano no longer diminishes in weight, which is ascertained by weighing it again and again, after three or four hours' suspension; the loss indicates the proportion of water.

[The remainder of the 100 grains which have thus been suspended over the concentrated acid are now put into a platinum capsule or crucible, and submitted to a low red heat, which should be continued until all the organic matter is completely incinerated and reduced to white ashes. The combustion of the organic matter is accelerated by stirring. The free ammonia, uric acid, and other nitrogenized and organic matters, are thereby decomposed or volatilized, and their collective quantity may be at once estimated from the loss sustained, which loss, deducting the amount of water first determined, should not be less than from 52 to 60 per cent. See, however, the remarks at the end of this article.]

SECOND OPERATION.

The proportion of the soluble and of the insoluble salts, &c., may be ascertained as follows:—

GENERAL EXAMINATION.—Take the ashes which were left after the ignition of the 100 grains of the guano under examination, and having weighed them as above directed, triturate and boil them in distilled water. A portion will be taken up by the boiling water, leaving a residuum insoluble in water.

The soluble salts taken up by the boiling water may consist of sulphate of soda, chloride of sodium (common salt), phosphate of soda, &c., as above said.

The salts insoluble in the boiling water, may consist of phosphates of lime, of magnesia, oxalate of lime, alumina, sand, &c.

The soluble portion must then be separated from the insoluble one, by filtering, and after washing the insoluble mass on the filter, and drying it, it is weighed; the loss indicates, of course, the amount of the soluble salts, which in good guano should amount to at least from 5 to 10 per cent.

Special Examination.—The aqueous solution, filtered from the insoluble portion above alluded to, and which contains the soluble salts of alkalies, should now be measured into three equal portions.

The first portion being acidified with nitric acid, a solution of nitrate of baryta is added, until a precipitate ceases to be produced. This precipitate is sulphate of baryta; the liquor containing it should be heated, in order to agglomerate it well, after which it is collected on a filter, washed, ignited, and weighed. This precipitate indicates, of course, the proportion of sulphuric acid contained in the sample of guano, in the state of soluble sulphates of alkalies. 117 grains of sulphate of baryta represent 40 grains of dry sulphuric acid, or 88 grains of sulphate of potash, or 72 grains of sulphate of soda.

In stating the results of the analysis, the amount of sulphuric acid found is taken as sulphate of lime (supposing that base to be present), and if there be more sulphuric acid than will form a sulphate with the lime, subsequently found, the rest is calculated and taken account of as sulphate of potash, and then as sulphate of soda.

To *the second portion* of the filtrate, solution of nitrate of silver is added, as long as a precipitate, or a turbidness is produced, the whole is then gently heated, in order to agglomerate the precipitated chloride of silver, which is then collected on a filter, washed, dried, fused in a porcelain crucible, and weighed. 144 grains of chloride of silver represent 36 grains of chlorine, and, consequently, 60 of chloride of sodium, or 76 of chloride of potassium.

In stating the results of the analysis, the amount of chlorine is calculated as chloride of sodium, and the surplus as chloride of potassium.

The third portion is tested for phosphoric acid, in which it is determined in the state of perphosphate of iron, as follows:—Take a certain quantity of pianoforte wire, which must be equal to at least twice the weight of the phosphoric acid suspected to be present in the liquor, and dissolve it in pure and hot nitric acid. Mix this solution with that of the liquor under examination, and add an excess of ammonia. This produces a reddish-brown precipitate, which is a sign that the quantity of persalt of iron added is sufficient, for otherwise the precipitate would be white, whitish, or yellowish-white. Heat is applied, and after a little time, this bulky precipitate should be collected on a filter, thoroughly washed with hot water, and when completely dry, it is strongly ignited, and weighed. From the weight of the ignited perphosphate of iron, the quantity of the phosphoric acid in the solution is ascertained, by deducting from it the amount of the peroxyde of iron, which is known from the quantity of iron employed; the difference indicates the amount of phosphoric acid present in that portion of the filtrate, and consequently, in the sample of guano submitted to analysis.

Each grain of metallic iron employed gives 1·6309 grains of peroxyde of iron.

Each grain of basic perphosphate of iron ($2\ Fe_2\ O_3,\ 3\ Ph\ O_5$) contains 0·42784 grains of peroxyde of iron, and consequently, 0·57216 grains of phosphoric acid.

This method of determining the amount of phosphoric acid is accurate, but it requires great attention on the part of the analist, for any loss which may happen during the operation bears altogether upon the phosphoric acid.

The liquors filtered from the precipitates produced in the three portions, as above said, should now be mixed together, and a small quantity of sulphuric acid, of hydrochloric acid, and of oxalate of ammonia, should be added thereto, for the purpose of precipitating the excess of nitrate of silver, and of nitrate of baryta employed, and also any lime which may be present in the liquor. The precipitates which are thus produced must be separated by filtering, and the filtrate is then evaporated to dryness, and ignited, in order to expel the ammoniacal salts. A little water should now be poured upon the ignited residue, just in sufficient quantity to redissolve it, and the solution being first acidified with a little hydrochloric acid, an excess of a solution of perchloride of platinum is poured into it, which precipitates the potash in the state of double chloride of potassium and platinum. Strong alcohol should be added, and the precipitate, having completely settled, may then be collected on a filter, washed with spirits of wine, carefully dried at 212° Fahr., and weighed.

Each grain of potassio-chloride of platinum ($Pt\ Cl_2$, KCl) represents 0.19297 of potash, or 0.30541 of chloride of potassium. The rest of the filtrate contains only the soda.

The proportion of phosphoric acid present in the guano, in the state of soluble phosphate, may also be determined, by pouring in the liquor filtered from the ashes left after the ignition of 100 grains of the guano, an excess of ammonia, and then a solution of sulphate of magnesia, previously mixed with as much sal ammoniac as will prevent ammonia from producing a precipitate in it. This mixed solution of sulphate of magnesia and sal ammoniac, should be poured in the filtered liquor above mentioned, as long as a precipitate continues to be produced. The whole is then left at rest for about twelve hours, in order that the precipitate may settle well; it is then collected on a filter, washed with water containing some ammonia, as long as the filtering liquor is rendered turbid when tested by a solution of chloride of barium. The precipitate is then dried, submitted to an intense heat in a covered platinum crucible, and when cold it is weighed.

Each grain of pyrophosphate of magnesia ($2\ MgO\ PhO_5$) contains 0.63363 of phosphoric acid.

THIRD OPERATION.

General Examination.—The weighed portion of ashes which could not be dissolved in water, and which consists of the earthy salts and silica or sand as before said, should be digested at a moderate heat in dilute hydrochloric acid, which will dissolve the carbonates and phosphates of lime and of magnesia, and the sand (which is recognized by its grittiness) mixed perhaps with a little alumina, is left undissolved, and may be collected on a filter, washed, dried, ignited, and weighed. The proportion of silica in good guano should never exceed from 3 to 4 per cent.

If, on pouring the hydrochloric acid on the insoluble residuum, an effervescence is produced, it is owing to a disengagement of carbonic acid, and indicates, generally, the presence of oxalate of lime in the guano, the oxalate having been converted into carbonate by ignition.

The insoluble residuum may not only consist of sand and alumina, as just said, but likewise of sulphate of lime, some samples of guano recently imported containing sometimes considerable quantities of this substance.

Special Examination.—To ascertain whether the insoluble portion contains sulphate of lime, the operator should pour upon it about 500 times its weight of pure distilled water, and leave it to digest for about twelve hours; sulphate of lime, being soluble in 430 parts of cold water, and in 460 parts of boiling water, will be taken up, and as its solubility is increased by common salt and also by sal ammoniac, a little of either of these two substances had better be added. After having digested the residuum in water, as just said, the whole should be thrown upon a filter to separate the silica which may be identified by its grittiness.

The filtrate should now be divided into two equal portions, and if one of these portions being treated with solution of chloride of barium, and the other portion with oxalate of ammonia, a white precipitate is produced in both, it is owing to the presence of sulphate of lime. Chloride of barium should, in that case, be added to the first portion as long as a precipitate of sulphate of baryta continues to be produced. This precipitate having well settled, is collected on a filter, washed, dried, ignited, and weighed. Each grain of sulphate of baryta contains 0·34372 of sulphuric acid, and, consequently, 0·58432 grains of sulphate of lime.

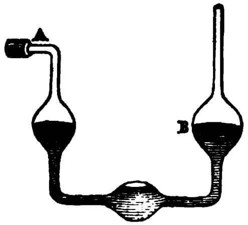
The liquor filtered in the first instance from the residuum, which was not dissolved by the hot hydrochloric acid, contains the phosphoric acid in solution. In order to separate it, a solution of perchloride of iron should be poured into it, and then an excess of ammonia, which should produce a reddish brown precipitate of perphosphate of iron. If the precipitate, instead of being reddish brown is white or whitish, it is a sign that the quantity of perchloride of iron employed is insufficient, and more of it must be added. The reddish brown precipitate should then be digested in hydrosulphuret of ammonia, by which it is converted into sulphuret of iron and phosphate of ammonia. After having left it to digest for a short time, the whole is thrown on a filter which retains the sulphuret of iron whilst the phosphate of ammonia passes through. After washing the precipitate, the phosphoric acid contained in the filtrate is precipitated in the state of double phosphate of magnesia and ammonia by means of a solution of sulphate of magnesia mixed with sal ammoniac, exactly as we described before. The amount of this phosphate in genuine guano should not be less than 14 per cent.

FOURTH OPERATION.

General Examination.—In the first operation we indicated how the amount of organic matter, of free and combined ammonia, and other volatilizable matter, can be estimated; but if the operator wishes to estimate the quantity of free ammonia and that of combined ammonia, uric acid, &c., he should proceed as follows:—

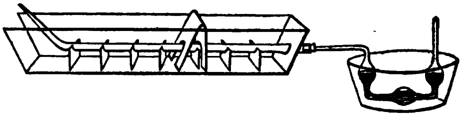
SPECIAL EXAMINATION.—Take a fresh portion of the guano under examination, and expose it to the heat of a steam bath, in order to dry it well. Whilst this is doing, prepare a mixture of hydrate of soda and of quick lime (if not kept ready), by pulverizing in a mortar one part of recently ignited potash or soda, with two parts of pulverized caustic lime. This mixture may be kept ready prepared in perfectly dry and wide-mouthed bottles, with air-tight glass stoppers.

Take now a bulb condenser, as represented in the fig., and charge it with pure hydrochloric acid of specif. grav. 1·13. This is readily accomplished by plunging one of the extremities of the tube in the acid, and sucking at the other extremity, until the acid reaches the level indicated in the fig. The extremity A of the tube passes through a cork, which must be soft, and of the very best quality.



Weigh off now 20 grains of the guano, previously well dried at a steam heat, as above said, and mix them with 200 grains of the alkaline mixture of soda-lime above alluded to. The mixing of the guano with the soda-lime should be effected in a slightly warmed and unglazed porcelain mortar. The mixture must now be introduced into a combustion tube of hard glass, about 16 or 18 inches long, and $\frac{3}{4}$ of an inch in diameter, represented in the adjoining figure. The mortar is rinsed with a little quantity of the soda-lime mixture, which is also introduced into the tube with that already put there; a little plug of ignited asbestos should then be loosely

placed over the whole, and the tube immediately connected with the bulb condenser above described, taking great care that the cork fits well, so that the connection may be air-tight. In order to make sure that the connection is air-tight the operator should bring a red hot piece of charcoal to the empty portion of the first bulb, near the cork, which will rarefy the air and expel a few bubbles of air from the apparatus; or the operator may simply suck a few bubbles out of the apparatus. If, on cooling, or after suction, the liquid remains at a higher level in the furthest bulb B, it is a sign that the connection is sound. This being done, heat is applied to the combustion-tube by means of spirit-lamps, but much more conveniently still, by the furnace usually employed in organic analysis. The whole apparatus is represented in the next figure.



The tube is then gradually surrounded with red hot charcoal, by degrees shifting the screen *c* and adding coals as the combustion advances, so as to produce a gradual expulsion of the ammonia, accompanied by hydrogen and carburetted hydrogen, which two latter gases, not being absorbable by the hydrochloric acid in the condenser, show the rate at which the combustion is going on. The heat applied at first should be moderate, in order to prevent too rapid a disengagement, of gas; yet this disengagement should take place uninterruptedly, for otherwise the acid might ascend into the tube and spoil the experiment. The disengagement should therefore proceed rather briskly than otherwise, the heat being gradually increased, until towards the end it has attained a good red heat. When the evolution of the gas ceases and the mixture in the tube has become *white*, the experiment is at an end. The point *a* of the combustion-tube should then be broken, and the ammonia which remains in the tube is expelled by sucking gently at the extremity *b* of the bulb condenser. The bulb condenser should then be disconnected and emptied into a porcelain capsule; an excess of a solution of chloride of platinum is added to the acid-liquor, and the whole is slowly evaporated to dryness in a steam-bath. The residuum should be treated with a mixture of two volumes of alcohol and one of ether, in order to dissolve the excess of chloride of platinum employed, and the ammonia chloride of platinum thus obtained, being washed with the above mixture, until it passes colourless and neutral through the filter, is dried at 212° Fahr., and then weighed. 225 grains of ammonia chloride of platinum represent 14 of nitrogen, or 17 of ammonia; or each grain of ammonia chloride of platinum represent 0·0763 of ammonia.

The quantity of ammonia may also be estimated by filling the bulb apparatus with a known quantity of hydrochloric acid of a known strength, and testing the acid of the bulb after the experiment, with a test-solution of ammonia, as in acidimetry.

Let us suppose, for example, that the bulbs of the condenser have been filled with hydrochloric acid of such strength, that 100 grains-measure of it represent, or are capable of saturating, 17 grains of ammonia, and diluted with a quantity of water, sufficient to fill up the bulbs. Let us suppose, also, that after the experiment, the hydrochloric acid in the bulbs previously reddened by a small quantity of litmus, being tested with 1000 grains-measure of a solution of test-ammonia, spec. grav. 0.992 (1000 grains-measure of which contain exactly 17 grains of ammonia), it is found in pouring it from the alkalimeter into the hydrochloric acid under examination, that 89 divisions of the alkalimeter have been required to neutralize the acid. Since the acid in the bulbs, which should have saturated 100 divisions (1000 grains-measure) of the ammonia test-liquor, have required only 89 such divisions, it is evident that it has already neutralized as much ammonia from the guano as are represented by 11 divisions of the ammonia test-liquor, and that it therefore contained 1·87 of ammonia.

$$100 : 17 : : 11 : x = 1·87.$$

The operator having experimented upon 20 grains of guano, the 1·87 of ammonia must of course be multiplied by 5 to obtain the per centage 1·87 × 5 = 9·35 per cent. of ammonia, that is of available ammonia contained in the sample in the free state, or in the state of ammoniacal salts, or of nitrogenized organic matter capable of yielding the volatile alkali by spontaneous decomposition.

Amongst the constituents of guano, shown in the analysis of that substance, given at the beginning of this article, is urate of ammonia, which is one of the most valuable constituents of guano, but not always to be met with in it, for it exists only in the very best guano. The detection of that substance, and its quantitative determination, is, therefore, extremely important. This may be accomplished by treating 100 grains of the guano with a solution of caustic potash, and boiling. The solution is then filtered, and a slight excess of dilute hydrochloric acid is then poured in, which produces a bulky crystalline precipitate, which is uric acid. It should be separated by filtering, washed with spirits of wine, and identified as uric acid by mixing it with nitric acid, and evaporating it carefully to dryness; the dry residuum should be crimson, and assume a bright purple colour by moistening it with ammonia. Each grain of uric acid represents 1·1012 of urate of ammonia.

The specific gravity of guano should be from 1·60 to 1·75, if above that the guano contains more sand than should be.

From what we have said, guano may be considered as a mixture of ammoniacal salts and of earthy phosphates; the ammoniacal salts are more abundant in Peruvian than in African guano, but the latter contains more phosphates.

As a general rule, the purchaser of guano should choose it as dry as possible. Good guano, exposed at a heat of 212° Fahr. does not lose more than from 6 to 12 per cent. which includes a little ammonia. Bad guano, or that which is in a state of advanced decomposition, loses sometimes as much as 35, or even 40 per cent. of water.

A light colour, when the guano is genuine, indicates a less advanced state of decomposition, and guano is therefore better.

If it have a strong ammoniacal smell, it contains free ammonia; and if it have no such smell, it should evolve it when mixed and triturated with a spoonful of slaked lime; such guano contains *potential* ammonia, that is, ammonia which will eventually be produced from the spontaneous decomposition of uric acid and other nitrogenized matter. Potential ammonia exists only in good and dry guano.

COMPARATIVE VALUE OF MANURES.

The base on which the following table, by M. M. Boussingault and Payen, is constructed, is the amount of nitrogen which each of the various substances, compared with each other, contains. M. Boussingault calls normal manure that which is obtained from the stables in which animals, receiving a liberal amount of food and a sufficient quantity of litter to absorb their excrements, are kept. To such farm-yard manure (previously dried, and generally containing in that state about two per cent. of nitrogen,) taken as the unit or standard of comparison, all the other nitrogenized substances mentioned in the table are referred. They consider, that as it is the nitrogen in a state of combination which is especially useful, it is the proportion of that substance which, when ascertained, indicates the richness of the manure. The reader must, however, bear in mind, that as it is not nitrogen only which constitutes the efficiency of manures, the more or less beneficial action of which depends also upon the various other mineral and saline ingredients which they contain, and also upon their physical condition, this table does not indicate, in an absolute manner, the relative value of those various manures. It is also necessary to remark, that the quality of farm-yard manures varies according to the kind of animals which produce it, and according to the species and quantity of food or fodder, and of litter, with which they are supplied.

In the first column of this table, given in the following pages, we have put the names of the various manures in alphabetical order.

The second column indicates the quantity of water contained in 100 parts in weight of the manures.

In the third column we have the quantity of nitrogen contained in 100 parts in weight of the dried manure; and in the fourth, the quantity of that substance in the manure in its ordinary or normal state.

The fifth column, entitled Values, is divided into two columns, A and B;—A indicates the value of each manure, supposed dry, compared to that of dry farm-yard manure, taken as standard, and represented by 100. B indicates the value of each manure in its usual or normal moist state, compared with the value of farm-yard manure, in its usual or normal moist state, taken as standard, and represented by 100.

The sixth column, entitled Equivalents, is subdivided into two columns, and it indicates the respective weights which, by virtue of the nitrogen which the manures contain, may be employed to produce the same effect, or which are necessary to replace, or be used instead of 100 parts in weight of farm-yard manure. Thus, for example, if 100 cwt. of farm-yard manure, containing 0·4 per cent. (and, consequently, nearly 45 lbs. of nitrogen), were required to manure one acre of ground, 8·02 cwt., that is (8 cwt., 0 qrs. 2¼ lbs.), of guano, should produce the same effect, and so in proportion with the other manures mentioned in the table.

TABLE OF THE COMPARATIVE VALUES AND EQUIVALENTS.

Translated from Messrs. Boussingault and Payen's Table, and arranged in Alphabetical order.

1	2	3	4	5		6	
				Values.		Equivalents.	
NAMES.	Normal Water.	Nitrogen in 100 Parts of the substance dried.	Nitrogen in 100 Parts of the substance in normal state.	A Dried Matter.	B Matter in normal state.	Dried Matter.	Matter in normal state.
Animal charcoal of refineries	47·7	2·04	1·060	104·6	265·0	95·58	37·73
Animal charcoal, do. (Mayenne)	27·65	1·901	1·375	97·4	343·7	102·50	29·09
Animal charcoal, do. (English)	13·45	8·022	6·952	411·4	17·38	24·30	5·75
Animal marine plants	12·54	2·756	2·408	143·9	602·0	71·10	16·61
do. do.	11·72	2·714	2·395	139·2	598·8	71·80	16·70
Ashes of Picardy	9·20	0·71	0·650	36·4	162·5	274·64	61·50
Beet-root lees and scum	67·0	1·579	0·535	80·9	133·8	123·4	74·77
do. exhausted slices	94·5	1·758	0·009	90·2	2·25	110·9	4444·4
do. pulp	9·3	1·26	1·14	64·1	285·0	154·7	35·08
do. do.	70·0	....	0·378	64·1	85·0	....	105·8
Blood, dried soluble	21·43	15·503	12·18	195·0	3045·0	12·57	3·28
do. dried insoluble	12·5	17·0	14·875	871·8	3718·8	11·47	2·69
do. liquid	81·01	....	2·945	795·0	736·3	....	13·58
do. do.	82·5	....	2·712	795·0	678·0	....	14·74
do. coagulated and pressed	73·45	17·0	4·514	871·8	1128·5	11·47	8·86
do. refuse of Prussian blue	53·40	2·8031	1·306	143·7	326·5	69·5	30·63
Bones after digestion at 230 F.	7·49	7·58	7·016	388·7	1754·0	25·72	5·70
do. do. moist	30·0	....	5·306	....	1326·5	....	7·54
do. undigested	8·0	....	6·215	....	1553·8	....	6·43
Branches and leaves of box	59·26	2·89	1·17	148·2	292·5	65·5	34·04
Brewers' grains	6·0	4·90	4·51	251·3	1127·5	39·7	8·8
Broom	10·4	1·37	1·22	70·3	305·0	142·3	32·78
Cake of linseed	13·4	6·20	5·20	307·7	1300·0	32·05	7·69
„ of colza	10·5	5·50	4·92	282·0	1230·0	35·45	8·13
„ of arachis hypogea	6·6	8·89	8·33	455·9	2082·5	21·93	4·8
„ of madia sativa	11·2	5·70	5·06	292·3	1265·0	34·2	7·9
„ of seeds of cotton	11·02	4·524	4·02	232·0	1005·0	43·1	9·95
„ „ of camelina	6·5	5·93	5·515	304·1	1378·75	32·8	7·25
„ „ of hemp	5·0	4·78	4·21	245·1	1052·25	40·80	9·50
„ „ of poppies	6·0	5 70	5·36	292·3	1340·0	34·2	7·46
„ „ of beech-nuts	6·2	3·53	3·31	181·0	827·5	55·2	12·08
„ „ of walnuts	6·0	5 59	5·24	286·6	1310·0	34·8	7·63
„ „ „ „	10·0	3·92	3·54	201·0	885·0	49·7	11·29
„ „ „ „	7·67	0·58	0·54	29·7	135·5	361·1	74·07
Clover (roots)	9·7	1·77	1·61	90·8	402·5	110·16	24·84
Cockchafers	77·0	13·931	3·204	714·4	301·0	13·99	12·48
Crysalides of silkworms	78·50	8·987	1·942	460·5	485·5	21·6	20·60
Cyder apples	6·4	0·63	0·59	32·3	147·5	309·5	67·79
Dung of the inns of the south	'60·58	2·083	0·79	106·8	197·5	93·6	50·63
„ of goats	46·0	3·93	2·16	201 5	540·0	49·6	18·5
„ of pigeons	9·6	9·02	8·30	462·6	2075·0	21·14	4·8
„ water of dunghills	99·6	1·54	0·059	78·9	14·75	126·6	677·9
„ of cows, solid	85·9	2·30	0·32	117·9	80·0	84·78	125·0

Table of the comparative Values and Equivalents, continued.

1	2	3	4	5 Values.		6 Equivalents.	
NAME.	Normal Water.	Nitrogen in 100 Parts of the substance dried.	Nitrogen in 100 Parts of the substance in normal state.	A DriedMatter.	B Matter in normal state.	Dried Matter.	Matter in normal state.
Dung of cows mixed with their urine	84·3	2·59	0·41	132·8	102·5	75·28	97·56
„ of horses, solid	75·3	2·21	0·55	113·3	137·5	88.2	72·7
„ „ mixed with their urine	75·4	3·02	0·74	154·9	185·0	64·56	54·0
„ of swine	81·4	3·37	0·63	172·8	157·5	57·86	63·4
„ of sheep	63·0	2·99	1·11	153·3	277·5	65·2	36·0
Dutch manure	44·12	2·478	1·36	127·1	340·0	78·6	29·40
Farm-yard manure	79·3	1·95	0·40	100·0	100·0	100·0	100·0
Feathers	12·9	17·61	15·34	903·1	3835·0	11·07	2·60
Fish—codfish, salted	38·0	10·862	6·70	557·0	1675·0	17·95	5·97
„ do. washed and pressed	10·0	18·74	16·86	961·0	4215·0	10·40	2·37
Flemish manure	....	....	0·19	....	47·5	....	210·5
do. do.	....	....	0·22	....	55·0	....	181·8
Flesh (dry) muscular	8·5	14·25	13·04	730·8	3260·0	13·68	3·06
Fucus digitatus	39·2	1·41	0·86	72·3	215·0	138·29	46·5
do. do.	40·0	1·58	0·95	81·0	237·5	123·4	42·1
do. saccharinus	40·0	2·29	1·38	117·4	345·0	85·2	28·9
do. do.	75·5	....	0·54	....	135·0	....	74·07
Glue (refuse of bone-glue)	42·0	0·912	0·528	46·8	132·0	213·8	75·75
„ (refuse of glue)	33·61	5·625	3·734	288·5	933·5	34·6	10·71
Grapes (residue of)	48·2	3·31	1·71	169·7	427·5	58·9	23·39
do. do.	....	3·56	1·83	182·6	457·5	54·77	21·85
Grass of a natural meadow	87·5	4·29	0·53	220·0	132·5	45·45	75·47
Greaves	8·18	12·934	11·875	663·2	2968·75	15·07	3·36
Guano imported into England	19·56	6·201	4·988	318·0	1247·0	31·4	8·02
do. imported into France	11·28	7·047	5·398	361·4	1349·5	26·3	7·41
do. cleaned by sifting	23·40	15·732	13·950	806·8	3487·5	12·4	2·87
Hair of oxen	8·9	15·12	13·78	775·4	3445·0	12·89	2·9
Hops (residue of)	73·05	2·228	0·60	114·3	150·0	87·6	66·66
Horn (raspings of)	9·0	15·78	14·36	809·2	3590·0	12·35	2·78
Kelp	3·8	0·40	0·38	20·5	95·0	487·5	105·26
Leaves.							
Autumnal leaves—							
of acacia	53·6	1·557	0·721	29·8	180·3	125·2	55·48
„ beech	39·3	1·906	1·177	97·7	294·3	102·3	33·98
„ oak	24·99	1·565	1·175	80·3	293·8	124·6	34·04
„ pear-tree	14·5	1·53	1·36	78·5	340·0	127·4	29·41
„ poplar	51·1	1·166	0·538	59·8	134·5	167·2	74·35
Leaves (green) of beet root	88·9	4·50	0·50	230·8	125·0	43·3	80·0
Do. do. carrots	70·9	2·94	0·85	150·8	212·5	66·3	47·0
Do. do. heath	7·0	1·90	1·74	97·4	435·0	102·6	22·9
Litter of silk worms, 5th age	14·29	3·483	3·285	178·6	821·3	56·0	12·18
Do. do. 6th age	11·39	3·709	3·290	190·2	822·5	52·6	12·16
Madia sativa (green)	70·55	1·534	0·45	78·6	112·5	127·1	88·8
Marl	1·038	0·517	0·512	26·5	128·0	377·17	78·1
Mould	....	1·03	...	52·8	....	189·0	....

Table of the comparative Values and Equivalents, continued.

1	2	3	4	5 Values.		6 Equivalents.	
NAME.	Normal Water.	Nitrogen in 100 Parts of the substance dried.	Nitrogen in 100 Parts of the substance in normal state.	A Dried Matter.	B Matter in normal state.	Dried Matter.	Matter in normal state.
Mud of river Morlaix	3·7	0·42	0·40	21·5	100·0	464·28	100·0
Oyster-shells	77·9	0·40	0·32	20·5	80·0	487·5	125·0
Potatoes (juice of)	95·4	8·28	0·070	424·6	17·5	23·5	571·42
do. (pulp of)	73·0	1·95	0·526	100·0	131·5	100·0	76·09
Poudrette of Belloni	12·5	4·40	3 85	225·6	962·5	44·3	10·3
do. of Montfaucon	41·4	2·67	1·56	136·9	390·0	73·0	25·6
Sawdust of acacia wood	25·0	0·38	0·29	19.5	72·5	513·2	137·9
do. do.	25·0	0·31	0·23	15·9	57·5	629·0	173·9
do. of fir wood	24·0	0·22	0·16	11·3	40·0	886·4	250·0
do. do.	24·0	0·31	0·23	15·9	57·5	629·0	173·9
do. of oak	26.0	0·72	0 54	36·9	135·0	256·9	74·0
Seeds of white lupin	10·5	4·35	3·49	223·1	872·5	44·8	11·46
Shells (sea)	....	0·052	0·052	2·6	13·0	3750·0	769·23
Soot from coals	15·6	1·59	1·35	81·5	337·5	122·64	29·62
do. from wood	5·6	1·31	1.15	67·2	287·5	148·85	34·78
Stalks of Jerusalem artichoke	12·9	0·43	0·37	22·0	92·5	453·5	108·1
do. of madia sativa	14·3	0·66	0·57	38·8	142·5	295·45	70·17
do. of potatoes	76·0	2·30	0·55	117·9	139·5	84·78	72·72
Straw of barley	11·0	0·26	0·23	13·3	57·5	750·0	173·9
do. of buckwheat	11·6	0·54	0·48	27·7	120·0	361·1	83·33
do. of lentil	9·2	1·12	1·01	57·4	252·5	174·0	39·6
do. of millet	19·0	0·96	0·78	49·0	195·0	203·0	51·23
do. of oats	21·0	0·36	0·28	18·5	70·0	541·76	142·85
do. of pea	8·5	1·95	1·79	100·0	447·5	100·0	22·3
do. of rye	12·2	0·20	0·17	10·3	42·5	975·0	235·3
do. do.	12·6	0·50	0·42	25·6	105·0	390·0	95·2
do. of wheat	19·3	0·30	0·24	15·4	60·0	650·0	166·66
do. do.	5·3	0·53	0·49	27·2	122·5	367·9	81·6
do. do.	5·3	0·43	0·41	22·0	102·5	453·5	97·5
do. do.	9·4	1·42	1·33	72 8	332·5	37·3	30·0
Starch (water of starch factories).	95·15	8·28	0·070	424 6	17·5	23·5	571·42
do. do.	99.25	8·28	0·062	424·6	15·5	23·5	645·16
do. (deposit of such water)	80·0	1·81	0·36	92·8	90·0	107·7	111·1
Urine of the cow	88.3	3·80	0·44	194·9	110·0	51·3	90·9
do. of the horse	79·1	12.50	2·61	641·0	652·5	15·6	15·3
do. of public urinals	9·57	17 556	16·853	900·3	4213·25	11·1	2·37
do. do.	96·889	23·108	0·715	1185·0	178·8	8·4	55·94
Woollen rags	11·28	20·26	17·978	1038·9	4494·5	9·62	2·22
Wheat chaff	7·6	-0·94	0·85	48·0	212·5	207·4	47·0

THE DISEASES OF CEREALS.

ON

THE DISEASES OF CEREALS,

PREVENTIVE AND CURATIVE METHODS.

THE diseases to which cereals are subject, are caused by certain conditions of the atmosphere, by certain parasitic plants or microscopic fungi, which, growing on these valuable grasses, exhaust their juices, distort them, prevent their coming to maturity, and sometimes smother and kill them. Another source of disease and death to cereals is to be attributed to an immense variety of noxious insects, which, feeding on the substance of these vegetables, either completely destroy them, or in a greater or less degree diminish the crop.

The diseases caused by parasitic plants, to which cereals are principally exposed, are:—

The MILDEW, called also blight or red-rust, produced by the *uredo rubigo.*

The SMUT, called also dust-brand, black blight, burnt corn, smut-brand, soot, black corn produced by the *uredo carbo.*

The CANKER, called also brand-bladders, pepper-brand, smut-ball, produced by the *uredo caries.*

The ERGOT or SPUR, caused by the *scleroticum clavus.*

MILDEW.

The disease known under the names of *mildew, blight,* or *red-rust,* is certainly the most formidable to which cereals in general, but more especially wheat and barley, are exposed. Rye seldom contracts this disorder.

According to Mr. Egremont (*Observations on Mildew*), of all the varieties of wheat, white wheat is more readily attacked by mildew than either red or spring wheat; the bearded wheat is less liable than any other sort to that disease.

Mildew is, as we said, caused by the *uredo cerealium* or *uredo rubigo;* it consists of pustules of an excessively small size, very numerous, of an oval form, yellowish or whitish at first, but which, splitting longitudinally, emit a dust, which is at first yellowish, and which, by exposure, becomes dark brownish-red, but never black. This dust consists of small globules. The fungus grows indifferently on both surfaces of the leaves, but more particularly on the upper surface, on the culm or stalk, on the husk, upon and within the floral envelopes and glumes of the corn plant; in a word, there is no period in the existence of these grasses, from the sowing to the reaping time, during which our crops can be considered safe from the invasions of this plague, nor is any part or portion of the plants, nor any soil or situation exempt from its attack. "The mildew is always in our fields waiting for a circumstance favourable to its outspread, and ready to destroy the expected harvest of the husbandman. So constantly present is this destructive disorder, that in the fairest fields of wheat grown in the richest corn districts of England, and, in its most genial years, I never saw a single acre entirely uninfected. Every year the farmer is more or less injured by this disease; for the produce of each acre of wheat is unquestionably reduced annually several bushels. Yet, those who suffer most by the loss, the farmers themselves, are almost universally ignorant of the fact; and their attention is rarely arrested by it till a year occurs in which their crop of wheat is nearly annihilated." (See *The Farmer's Encyclopædia.* by Cuthbert Johnson—article "Mildew.")

Mildew is remarkable for this peculiarity, that it is always the most vigorous plants which suffer most by it, and that the infection is more destructive in proportion as they progress towards maturity. Thus, if a young plant becomes mildewed, a shower of rain is often sufficient to clean and restore it to health; but if the mildew appear after the formation of the spikes, the fungus becomes more firmly fixed, takes up and appropriates to itself the nourishment which is required to develop and mature the seed, which, being thus literally left in a starving condition, remains small, is light, and totally or partially shrivelled up, yielding, in proportion to the severity of the disease, a more or less reduced quantity of flour, or scarcely any flour at all.

A plant is known to be mildewed when small specks or spots of an oblong shape, of a dingy white colour, are observed scattered here and there, generally on the upper surface at first, then on the under surface of the leaf and upon the stem, which specks or spots gradually extend on the whole plant and assume a rusty colour. Shortly afterwards, a fine dust of a brownish yellow colour, tasteless and odourless appears, which is sometimes so abundant that it actually stains the garments of the men, or the hairs of the animals, who may have passed through the infested field. This dust, seen through the microscope, consists of a multitude of small granules; at first it is yellowish, but by exposure it becomes of a dark rusty colour, and the name of *rust* is given to the disease; the dust crumbles off by the slightest touch, and the faintest breeze wafts it away, and sometimes carries it to considerable distances.

The following figures represent mildewed wheat:—

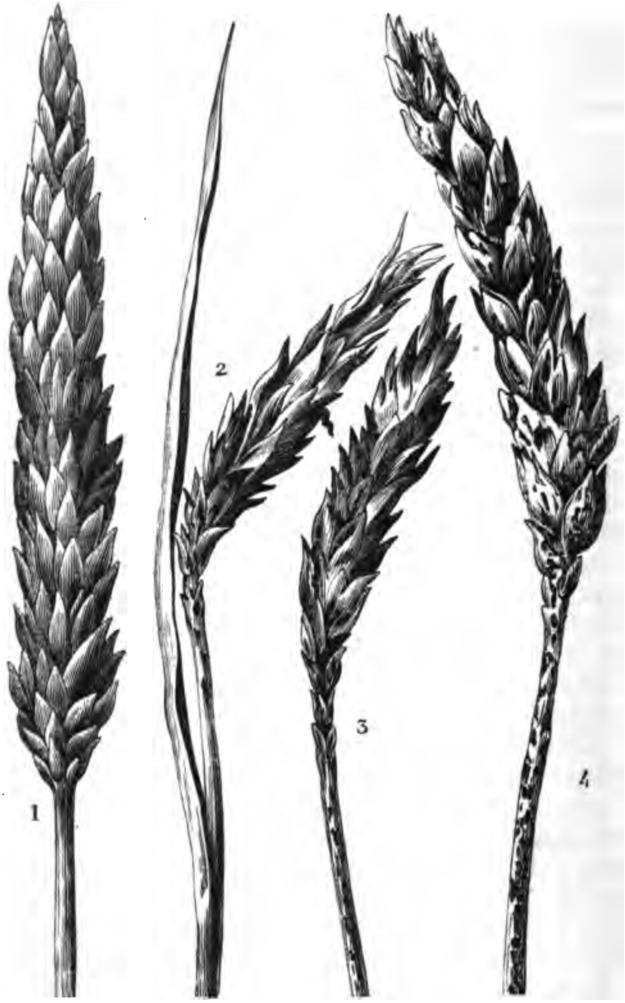
Fig. 1. Sound ear of wheat in a matured state.

Fig. 2. Young ear of wheat beginning to be mildewed.

Fig. 3. Mildewed ear of wheat in a more advanced stage.

Fig. 4. Ear of wheat completely mildewed in a ripe state.

Fig. 5. Leaf and stem of mildewed wheat.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According to Mr. Egremont (*Observations on Mildew*), the soils which appear most favourable to the production of mildew are the following, and in the order stated:—

Peat or moor,
Calcareous,
Calcareous loams,
Sand,
Sandy loams,
Grey earth, or
Strong adhesive clay.

Those fields which are in low and sheltered valleys, and which on that account are damp, are most liable to the invasion of mildew, and the disease is always most severe when a burning sun succeeds to rainy or foggy weather. It is stated that wheat is more readily attacked by this fungus when thin than when thick-sown. Thick-sowing, however, although it may render the distemper less formidable or frequent, does not prevent it ; in fact, no means of warding off the attacks of this insidious enemy are known; nor, from the difficulty of applying remedies to all the infected parts, can it perhaps be said that we possess a certain means of effectually curing the plants infested with mildew.

Heavy showers, by thoroughly drenching the plants, occasionally eradicate the tenacious fungus, and thus effect the cure; at other times, after having uselessly employed all sorts of remedies both empyrical and scientific, and when all hopes of accomplishing the desideratum were given up, the mildew will, as it were, of its own accord, and in some mysterious manner as yet unfathomed, vanish and disappear.

Experience however has taught that every process of culture which tends to promote a vigorous growth, such as high farming, or the use of saline manures, if it does not prevent mildew, at least checks its development in a very considerable degree; moreover, it has been observed that, in the neighbourhood of the sea wheat and other plants are rarely affected. This observation probably led to trying common salt as a remedy, for it appears to be now a well-authenticated fact that salt, though not a preventive, completely destroys the fungus wherever it touches it.

The mode of application consists in dissolving salt in water in the proportion of

½ lb. of common salt in
1 gallon of water,

and sprinkling the solution amongst the infested plants with a plasterer's brush, or otherwise. It is stated by Mr. Johnson that two men may get over about four acres a day, the one constantly carrying a fresh supply of the saline liquid to the other man who is sprinkling it about, as just said.

The application of salt to mildew acts instantaneously, the fungus being at once destroyed when touched by the solution, which should be used on a clouded day, or else in the evening. To ensure success, the operation should be repeated several times if necessary, in order to render the contact of the solution with the parts affected more certain.

SMUT.

The disease known under the name of *smut*, *dust-brand*, *smut-brand*, *black-blight*, or *black-mildew*, *burnt corn*, *black corn*, or *soot*, is much less destructive than the mildew. Oats, barley, wheat, maize, and almost every species of corn, are liable to be affected by this disorder, but wheat is less frequently attacked, and when attacked, less damaged by smut than the other cereals ; barley, however, and especially oats, are often most disastrously infested. All the varieties of oats, of barley, and of wheat, may become smutted, yet winter and bearded wheat are less exposed to the smut than the other varieties of wheat.

The smut, as we said before, is caused by an internal parasitic fungus, called by botanists *uredo carbo*, which grows generally within the flowers and ovaries of the corn, in consequence of which the farina of the grain is decomposed, and ultimately the grain, as well as the husk and other parts of the ear, become covered with an abundant black, or dark olive, inodorous powder which, in the fresh state, is somewhat viscid, but which, when dry, is very light, and easily dispersed by the winds or by the slightest touch. This black powder consists of an innumerable quantity of perfectly spherical, semi-transparent and very light gloubles, and appears only when the fungus has arrived at maturity, the black dust being in fact the reproductive element or *seed* of the smut, and at the same time almost the only criterion by which the farmer can recognize the disease.

Like mildew, the smut affects cereals in all soils and situations, it is a contagion from which no clime or country is exempt, yet hot and damp climates seem to be favourable to the development of this distemper, which although it may, and has sometimes, proved a great loss to the agriculturist, does not appear to communicate any deletrious property to the grain, or to the flour obtained from it.

Smut is recognized in wheat by the blackish colour of the ear, and also because, even before the ear has protruded, the upper leaf exhibits yellow spots, and its upper extremity is dry. This latter sign is conclusive, and, according to l'Abbé Tessier, when observed, the farmer may be sure that a smutty ear will follow. The black dust is, as we said, a sign that the fungus has come to maturity, but as this takes place long before reaping time, the black dust eventually dries up, or is washed away by rains, so that when the harvest time comes the grain is generally but little contaminated by it. On the other hand the disease generally does not affect all the crop, nor even the whole ear, some of the latter being found partly sound and partly smutted; in the ears, however, which have been severely attacked nothing remains but the stem and the chaff.

In *oats*, smut is detected because the diseased plants are of a paler green colour, smaller, and less robust and vigorous than the rest; the ear does not become well developed. Like mildew, the smut is often so abundant that it stains the farmer's garments, or the hairs of the animals which may cross the infested field; all the varieties of oats are subject to the distemper.

In *barley* smut is not so easily detected as in oats and in wheat, because the colour of a smutted ear of barley is much less black, and is not so easily washed away by rains; wherefore it is seldom that the ear of smutted barley is left in the state of a skeleton as in wheat.

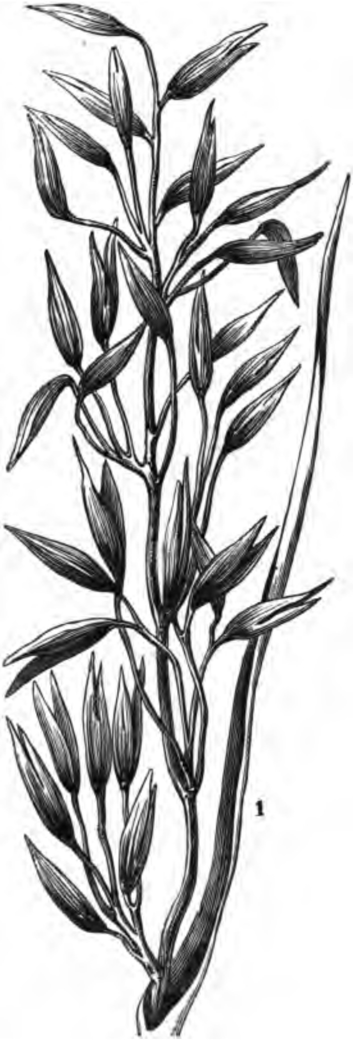
The following figures represent smutted wheat, oats, and barley :—

Fig. 1. Represents an ear of oats (*avena sativa*, or white oats) in the sound state.

Fig. 2. First stage of the smut in the ear of oats.

Fig. 3. Ear of oats completely covered with smut.

Fig. 4. Smutted ear of oats, dried up.



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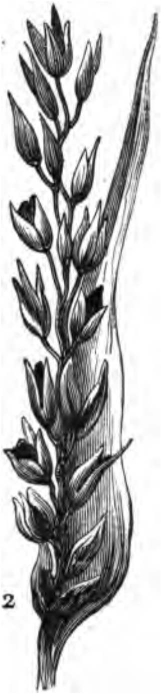

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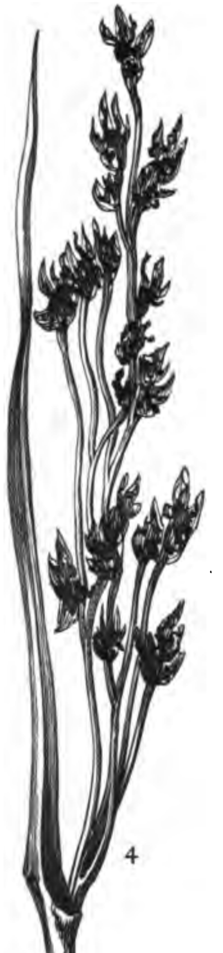


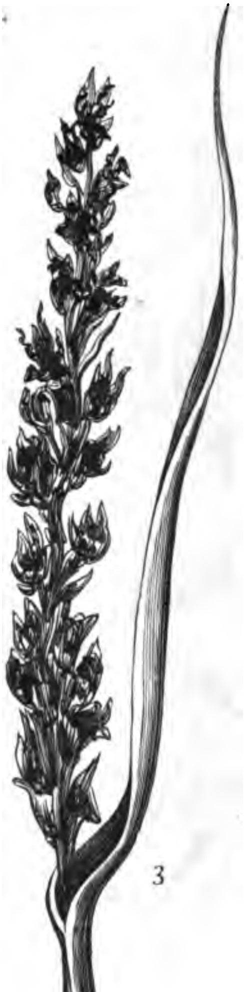


Fig. 1. Sound ear of wheat.
Fig. 2. Ear of wheat beginning to be infested with smut.

Fig. 3. Ear of wheat, partly sound and partly infested with smut.

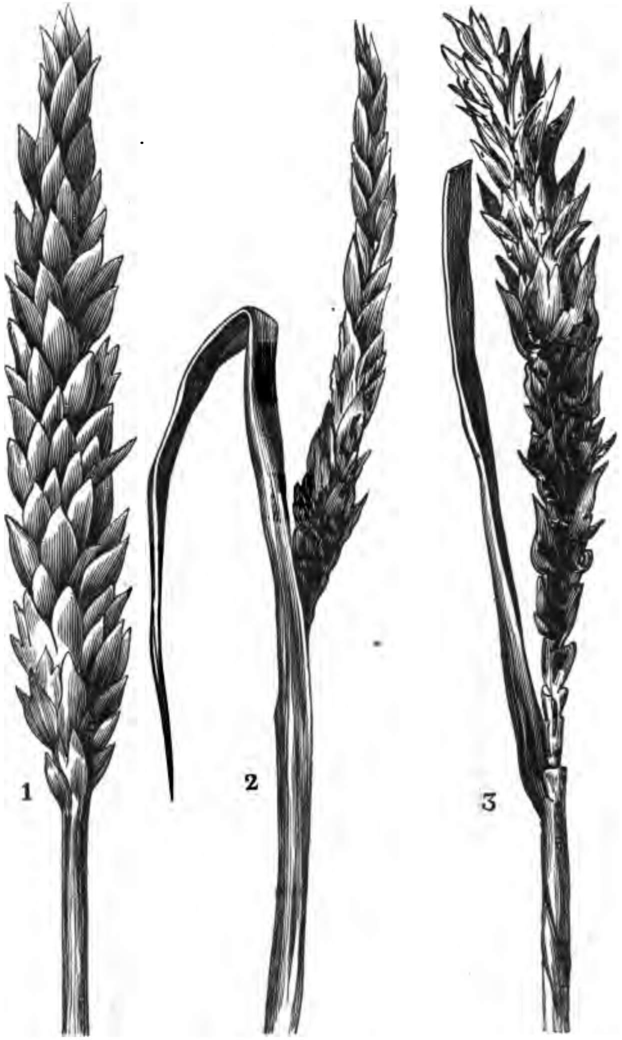
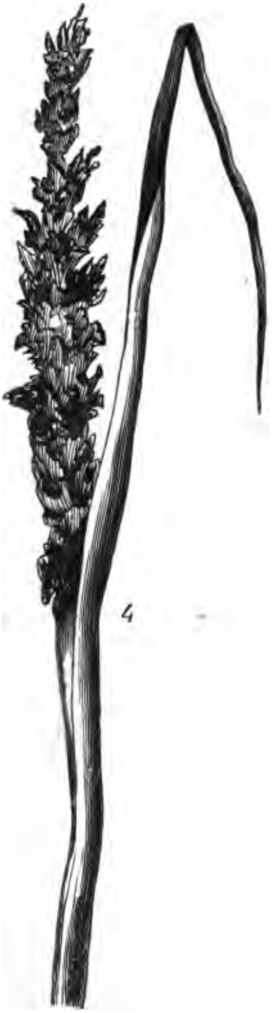


Fig. 4. Ear of wheat completely covered with smut.

Fig. 5. Ear of wheat completely covered with smut, and dried up.



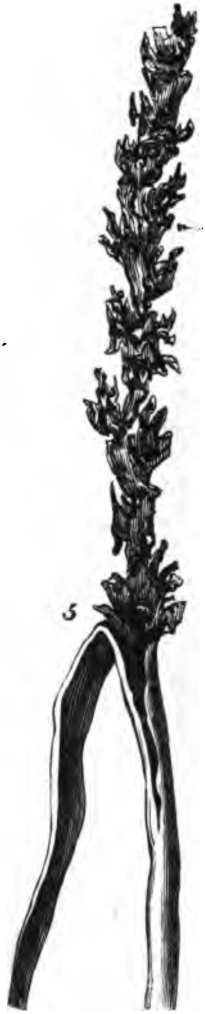
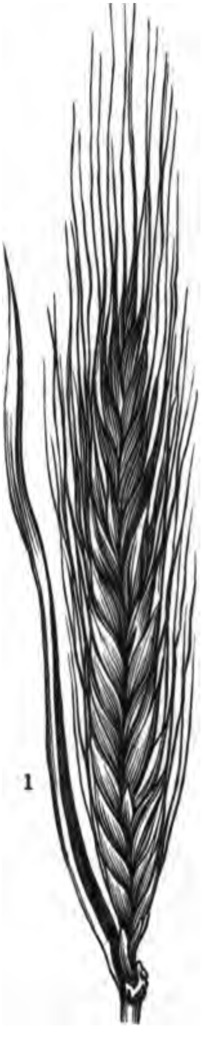


Fig. 1. Sound ear of barley.
Fig. 2. Ear of barley partly smutted.
Fig. 3. Ear of barley completely smutted.



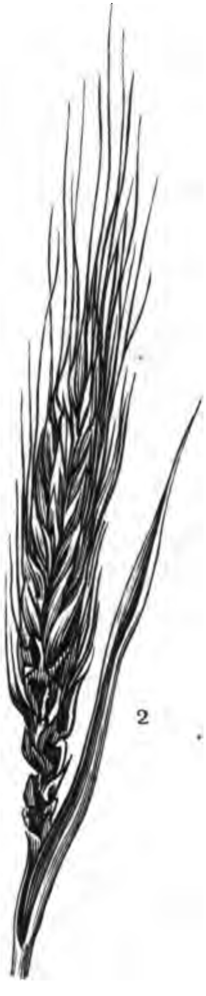
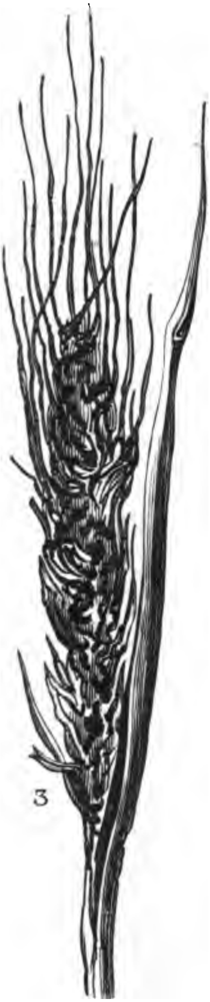
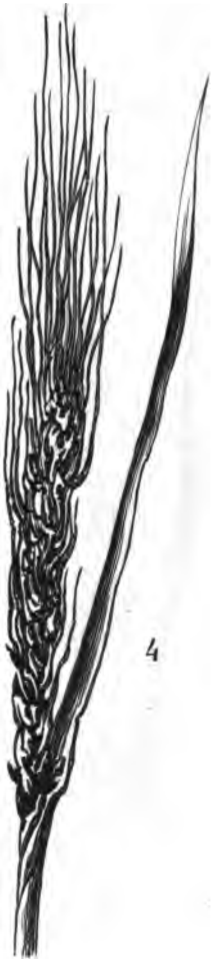


Fig. 4. Ear of barley completely smutted and dried up.





Mr. Kerby says, that the smut is the food of a small insect or beetle, of a shining black colour. (*Dermestes ater*, Marsham.)

The modes of preventing and curing the smut are the same as for the canker.

CANKER.

The disease called *canker*, *pepper-brand*, *brand-bladders*, or *smut-balls*, and which for a long time, and in this country, continues even now to be confounded with the smut, from which it greatly differs, as will be shown presently, is caused likewise by a parasitic fungus, called by naturalists the *uredo caries* or *uredo segetum*. This fungus grows within the seeds of the wheat, which eventually become distorted, and the farina of which is ultimately replaced by a softish compact matter of a greyish colour, similar to the substance of a mushroom. Gradually, as the disease makes progress, the greyish matter becomes more compact, and is at last converted into a dark brown or blackish, and exceedingly fine powder, which is rather unctuous to the touch and tasteless, but which, when rubbed between the fingers, has a most disagreeable smell of decayed fish. This powder is essentially different from the smut, for it never makes its appearance outside of the grain during the growth of the plant. This dust, however, is exceedingly contagious and a few grains, or even one single grain of cankered corn is sufficient to contaminate the sound grains, and thus cause great loss to the farmer. The contagious property of this fungus is in fact so excessive and subtle that it has been proved by well-authenticated experiments, that if the water employed to wash the affected grains comes in contact with other sound grains, they contract the disorder, and even if the stalks of the plants so affected be carried to the dunghill, the manure will become infected, and communicate the disease to the grains which may subsequently be sown into the soil after the application of such a manure, and a cankered crop will be the result. The disease is communicated more especially whilst threshing the sheaves, for the cankered or decayed grains being smashed by the operation, the fine light dust thus liberated, flies about, and alights on the sound grains, which thus contract the disorder. In fact any farming operation which will cause the rupture of the envelope of the cankered grains, and determine its contact with the sound ones is sure to inoculate the disease to the latter.

Wheat is more liable to this distemper than any other kind of corn, and common wheat (*triticum æstivum*), turgid wheat (*triticum turgidum*), Polish wheat (*triticum Polonicum*), more so than the other varieties of wheat.

Canker never attacks barley, rye, nor oats, but millet and Indian corn sometimes contract the disease, and this is the case also with various kinds of meadow grass.

The decay caused by the *uredo caries* does not always affect the whole ear of the wheat, for it frequently happens that both sound and cankered grains are found in the same ear; a cankered grain between two sound ones, and, *vice versa*, a sound grain between two cankered ones; nay, a cankered ear has often been found within the sheath of a, to all appearances, perfectly sound stem.

As we said before, the black powder of the *uredo caries* is essentially different from that of the *uredo carbo;* in effect the former is not dispersed by either wind or rain, and resists even the handling of the reaper, but when the threshing begins, the envelopes of the cankered grains burst, and not only contaminate the sound grains, as before mentioned, but determine a painful and itching sensation to the eyes of the threshers, and a more or less distressing cough, accompanied with difficulty of breathing and loss of appetite. The powder in fact acts like a poison, the effects of which however, soon disappear. The loss which in bad seasons accrues to the farmer from the canker is most disastrous, one-fourth or more of the product having been at times destroyed by the disease, added to which wheat thus contaminated suffers a great depreciation in price, even when but slightly affected.

It is only a practised eye that can detect a carious or cankered plant before it has eared, yet even at that early stage, distinctive or characteristic signs are not wanting, thus the leaves and stem are thinner and of a darker green than usual, but when the ear has protruded, the carious may be distinguished from the sound ear by its bluish hue, by its slenderness, and uncommon straightness, the awns are closer together, the grains are covered with a thick greenish skin, and if smashed between the fingers, the infect and characteristic odour before alluded to is immediately perceived. After a while, however, the cankered, ear instead of remaining slender, augments in size, and eventually becomes even larger, but is less green than the sound ear, whilst the awns are farther apart than ordinarily, the grains from whitish become greyish or greyish-yellow, and, at this stage it is not necessary to smash the grain in order to smell the characteristic and offensive odour which is quite perceptible without that.

Lastly, when the cankered ear has attained maturity, the stems are of a paler yellow colour, and shorter, the awns are whitish, the grains brownish, and filled with a black powder.

It is worthy of remark, that a cankered ear contains more grains than a sound ear, for according to M. Tessier, as many as sixty-eight grains have been counted in the former, which is a quantity very seldom found in the latter; after a time, the odour which is exhaled from a field containing a carious crop is insupportably fœtid. Carious grains are ordinarily shorter, and rounder, always obtuse, soft, dry, and very light. (See Tessier, *Traité des Maladies des Céréales.*)

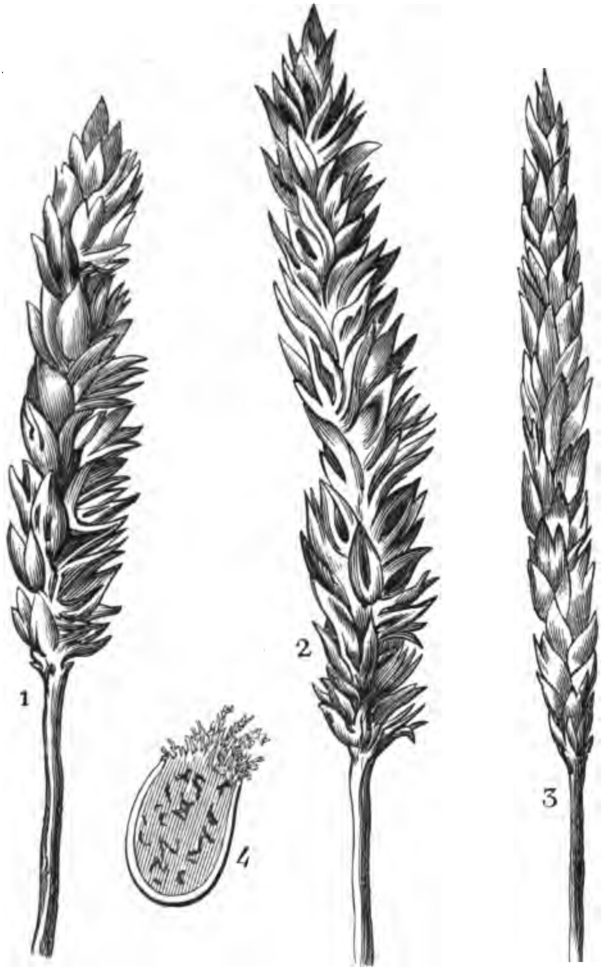
The following figures represent the various stages of the disease:—

Fig. 1. Ear of wheat partly carious and partly sound.

Fig. 2. Ear of wheat entirely carious and in maturity.

Fig. 3. Young ear of wheat in the first stage of caries.

Fig. 4. Longitudinal section of a grain of cankered wheat.



For preserving wheat from canker and smut, various substances may be employed; the most efficacious are quick-lime, common salt, sulphate of soda, alum, acetate of copper (*verdegris*), and sulphate of copper (*blue copperas*) sulphate of zinc (*white copperas*), arsenic (*arsenious acid*), realgar (*sulphuret of arsenic*), putrified urine, dunghill drainings, pigeons' dung, and in fact any substance or compound corrosive enough to decompose the parasitic fungus without disorganizing the grain. Some agriculturalists make mixtures of the above ingredients, such as lime and salt, lime and arsenic, lime and Glauber's salt, alum and arsenic, common salt and blue copperas, &c. &c.

But whatever be the method or mixture adopted, the grains which are to be subjected to *pickling* (as this operation is called) should be chosen perfectly clean and sound. They should be thoroughly washed with clear water, which should be renewed several times, taking care to let the waste water run into a sink, or gutter, so that it may not come in contact with any other grain or implement, and all the grains which are floating must be carefully removed. The grains being washed and cleaned, as just said, may now be treated with one of the pickles above mentioned. A good pickle consists in dissolving as much common salt in water as will form a solution strong enough to float a hen's egg. The grains washed and cleaned, as above said, are then soaked for twelve hours into that solution, after which they are ready for sowing.

Or, according to Mr. Bevan, one pound of fresh lime may be immersed into three gallons of boiling water, and after allowing the liquor to cool down, the clear supernatant water is decanted or carefully poured off, or syphoned out, and the clean wheat or corn may then be soaked in it for twelve hours, after which the grains should be withdrawn, drained, and then mixed with pulverized slaked lime, by tossing them about with a shovel, whilst the quick lime is sifted or otherwise carefully spread over it. They are then in a fit condition for sowing.

But perhaps the best and most successful method, is that proposed by M. Mathieu de Dombasle, which is said to yield the soundest and most productive grains.

For every two bushels of wheat cleansed as above said, take three lbs. of caustic lime, in lumps, and sixteen lbs. of Glauber's salt. Dissolve first the Glauber's salt, in six or seven quarts of water, and whilst the salt is dissolving, slake the lime, which is best done by putting the lumps of lime into a wicker-basket, and plunging the whole into water for about a quarter of a minute. The basket should then be withdrawn from the water, and its contents emptied upon the floor. In the course of a few minutes the lime will become very hot, and spontaneously crumble into powder. The wheat should now be put into a tub of suitable dimensions, and whilst an assistant is stirring it with a shovel, the solution of Glauber's salt above mentioned, must be poured upon it, until it is observed that all the surface of the corn is wet, and that the solution is in slight excess. The slaked lime, in fine powder, must now be gradually sprinkled over the mass of the corn in the tub, the workman carefully stirring it with his shovel, until each grain is uniformly covered with the lime. This being done, the corn should be shovelled out of the tub, and heaped up in a corner of the room where the operation has been carried, a fresh quantity of corn is then put into the tub, and treated in the same manner.

After the pickling, the corn soon becomes almost dry, and may be kept in that state for a few days without alteration, but if there be any fear of the mass becoming heated, it should be stirred, and tossed about with a shovel in order to cool it.

ERGOT, OR SPUR.

The spur or ergot, is a formidable disease, which may be said to be peculiar to rye, although wheat, Indian corn, and a few other graminous plants are subject to it. It is an excrescence, in the shape of an obtuse horn or spur, cartilaginous, hard, brittle, compact, of a greyish colour internally, but externally of a blackish purple colour, furrowed on two sides, and sometimes with fissures. The ergots occasionally exceed one inch and a half in length, the breadth is from half a line to four lines. The ergot is a fungus *(scleroticum clavus)* which grows upon the grain, and eventually becomes substituted for it. The sugar, albumen, and other constituents of the sound grain of rye have disappeared, and the ergot is found to contain ammonia, a nitrogenized matter, an oleaginous matter, and an excessively active principle known to chemists under the name of *ergotine*, to which the medicinal and deleterious effects of the ergot of rye are due.

The ergot of rye has a somewhat unpleasant, fishy, and sour odour, especially when fresh, but a single ergot is almost odourless, unless it be in powder, in which state it has a somewhat acrid and nauseous taste.

When the ergots are large, the ear contains but few, or only one of them, the plant remaining in other respects strong and healthy, and the other grains in the ear sound. An ear, however, contains generally four or five ergots only, though, according to L'Abbé Tessier, as many as twenty have occasionally been found upon a single ear. It frequently happens also, that a part only of the grain is ergotized, one half, or one-fourth part only of the grain, for example, being invaded by the fungus, has a dark or blackish purple colour, whilst the sound or unaffected portion retains, externally, the form and colour of healthy rye. In such cases the ergotized portion is always situate at the base of the grain.

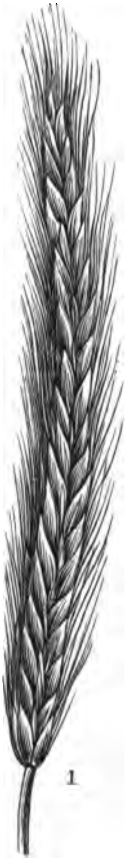
The ergot is a contagious disorder.

The soils which appear most favourable to the production of ergot, are those which are in low, sheltered, and damp situations; also poor sandy soils; and in rainy seasons, those which are at the foot of hills or declivities are also more subject to the infection than others. It would appear, that the ears which grow on the sides of fields are more frequently and more seriously affected than those which are in the middle. The ravages produced by this fungus in certain districts, are sometimes of the most disastrous character, not only on account of the loss in the crop, but because, as it is a poison to man and animals, the most distressing and fatal accidents have at times resulted from its becoming, accidentally or incautiously, ground with the flour, and consumed as food. The ingestion of ergot into the stomach produces cramps, palsy, emaciation, gripes, vomiting, abortion, gangrene, and death.

Ergotized rye is very easily detected in a field; the plants which are attacked by the disease are immediately recognized, even at a distance, by the black appearance of the grains.

The ergot is a disease against which there is no other preventive or curative remedy than by thoroughly cleansing the grain by winnowing, sifting, or, if necessary, handpicking.

Fig. 1. Sound ear of rye.
Fig. 2. Ergotized ear of rye.
Fig. 3. Grains of ergotized rye.
Fig. 4. Awn of ergotized rye.



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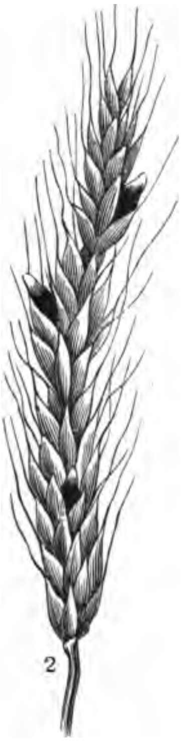

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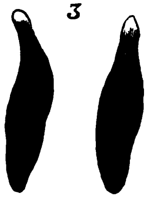

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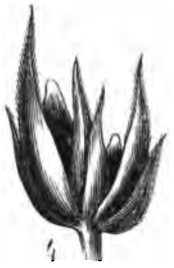

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INSECTS INJURIOUS TO CEREALS.

If the experience of every-day's life did not show us what great effects can be traced to small causes, the enormous influence which insects have on the produce of our fields would superabundantly illustrate the fact. Armed with a spear, a gun, a trap, or some other of the numerous engines of destruction which the mechanical arts put at his command, the farmer can, to a considerable extent, prevent the depredations of the more obvious beasts of prey; and though in his anxiety to preserve, and defend the treasures of his fields, he often mistakes a friend for a foe, still, upon the whole, he manages pretty well to ward off their attacks or keep them within limits; but insects equally set at nought his power, his vigilance, his weapons, and all his cunning devices: sheltered by their minuteness from his observation, and trusting to their numbers, the mighty tribe, heedless of weapons too gross to reach them, proceed mercilessly with their work of destruction, eat up, gnaw, spoil the richest crops, and sometimes lay waste whole tracts of land but lately luxuriant with vegetation, leaving the farmer struck with awe and despair, and though taught by the undeniable proof of his disaster, almost incredulous that such stupendous mischief should have been caused by what?—even by these mean and insignificant creatures, very *excrements of the earth*, who in myriads are transformed into enemies than whom none are more terrible, dauntless, or unconquerable, and against whom no other defence or barrier is available than such as is based on their very constitution and habits;—"When it is considered," says Mr. James Duncan (*Quarterly Journal of Agriculture*, vol. VIII.), "that the number of insect species inhabiting Britain is between ten and eleven thousand, that the individuals constituting these species exceed in most cases all calculation; and that the proportion of about one-half subsist entirely on vegetable substances, it becomes obvious that the aggregate amount of damage must be very considerable. . . . There is scarcely one of our most useful plants which is not assailed in one way or other; and the forms of insects, and their mode of living, are so intensely diversified, as to enable them to continue their depredations in all the different states of these plants. The various kinds of corn, for example, have a host of enemies in the subterraneous larvæ of beetles which consume the roots; various kinds of caterpillars feed on the blade; some particular species attack the ear; and even when laid up in apparent security, a small beetle is often found to scoop out the interior of each grain, and convert it into an abode for itself. The turnip, in like manner, is equally exposed to these depredators. If the seed of this useful plant escapes the attack of a minute weevil, another enemy awaits the unfolding of the cotyledon leaves, and a third buries itself in the bulbs and roots, which become diseased, and covered with unseemly excresence, while the mature foliage is often consumed by caterpillars. Many plants have a particular insect appropriated to them; others form the food of several different kinds; and when it happens from some mysterious cause, which we are at present unable to penetrate, that these creatures suddenly increase beyond their due proportion, the partial or entire destruction of some of our most valuable crops is occasionally effected by their agency. But even when there is no remarkable augmentation of their numbers, there is reason to believe that the injury occasioned to vegetation by insects is at all times greater than is generally supposed. Their operations are often carried on under cover, either beneath the surface of the soil, within the substance of the plant, or in other situations where they escape observation. Many kinds, again, feed only in the night, and conceal themselves during the day in holes and crevices. In consequence of this latent and insidious mode of attack, there is no doubt that we are often led to ascribe the unhealthiness and decay of plants to badness of soil, unfavourable weather, and other causes, when, in reality, they are produced entirely by insects. The attention of gardeners and agriculturists, moreover, is seldom directed to their depredations, unless when they become so extensive as to threaten serious injury to their crops; but it is obvious that they must be carried on to a greater or less extent every season, for the existence, at least, of the respective species is always maintained, and this can only take place at the expense of the plants on which they are destined to feed. Whether, therefore, they fall under our observation or not, there is always a host of minute depredators at work, which, in the instinctive prosecution of their own habits and economy, interfere in no inconsiderable degree with the interests of the agriculturist, by preventing the full return which many of his crops would otherwise produce."

The insects which are most injurious to grains are,—

The grub or larva of the common cockchafer (*melolontha vulgaris*.

The German or field cockchafer (*melolontha agricola Fabricius*).

Slugs (*limax*).

The wire-worm, grub, or larva, of the lined click-beetle (*elater lineatus*, Olivier; *cataphagus*, Stephens; *agriotes*, Erichson).

The corn weevil (*calandra granaria*, Clairville—*curculio granaria*—Linnæus).

The corn moth and corn worm (*tinea granella*—Linnæus

The alucite.

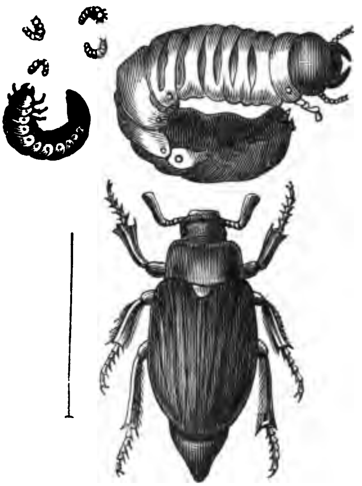
The gibbous ground beetle (*carabus*, *zabrus*, *gibbus*.—Fabricius).

The winter or dart-moth or winter corn moth (*agrotis noctua segetum*).

The wheat-fly, &c.

THE GRUB OR LARVA OF THE COMMON COCKCHAFER.

(*Melolontha Vulgaris.*)



However great may be the damage which the common cockchafer causes to vegetation, the larva or grub of that insect is much more noxious, for it is more voracious and more destructive than that of any other beetle; and as the female of the cockchafer deposits her eggs, from which the grub proceeds, in the best cultivated and richest soils, the mischief produced is sometimes incredible. During four or five months after their birth, the grubs live close together, but as soon as winter sets in, they burrow deep into the ground: at the beginning of the spring, however, they come nearer the surface, and then begin their depredations. They feed upon every kind of soft roots, and when in sufficient number, gardens and meadows have been devastated, fields of oats and of wheat were completely destroyed by the voracious appetites of these grubs.

The common cockchafer lays from twelve to forty eggs, which are deposited by the insect about six inches deep into the ground. The grubs require four years for their complete metamorphosis, the greatest damage is done during the third year of their growth, Several methods may be resorted to for the purpose of destroying these insects.

1st. *By destroying the cockchafer.* Early in the morning, when the dew is still on the trees, or during the middle of the day, when the weather is hot or sultry, the cockchafers will be found sitting at rest in preference on the oak, the willow, the hazel, and other fruit trees. If the trees are small, it is sufficient to shake them, and the cockchafers which fall on the ground may then be picked up, put into bags, and subsequently destroyed, either by burning them, or pouring boiling water upon them, or else, which is best, they may be given to the poultry. When the trees are large, it is impossible to shake them with sufficient force, it is therefore necessary to climb into them and shake the branches. It is advisable to spread sheets or bags on the ground, in order that the beetles which have fallen may be more easily seen and picked up. Early in the morning is the best time.

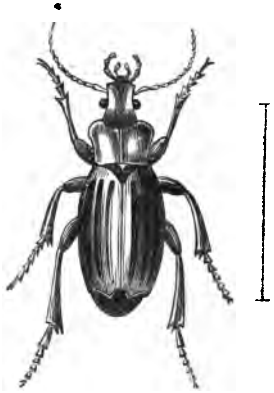
"Cockchafers are abundant throughout the south and west of England in the beginning of May. Very common near Swansea; and in 1814 every tree, bush, and hedge, was covered and nearly denuded by them. Not very common near Carlisle. Very plentiful about Gravesend where they are collected in innumerable quantities by the Dutch fishermen, Newcastle, Mildon-Park, Northumberland, Keswick," &c.—See *Stephens' Illustrations of British Entomology*, vol. iii. p. 223.

2. *By destroying the grubs.* — The presence of these grubs cannot, unfortunately, be detected in the ground except after the mischief is done. When a plant has been attacked by this grub, it looks yellow and withered, and falls down at the slightest touch; its root appears as if it had been cut through with a sharp instrument, and if the ground be then dug up the grub will be found in the neighbourhood—we say in the neighbourhood, because when a plant is completely withered the insect has left it for another, and must therefore be looked for at the

root of such plants which may begin to show signs of disease.

These grubs most generally abound in the lands which are newly cleared. One of the best methods of destroying them is by the frequent use of the plough, and by spreading upon the fields infested by them common soda-ash, in the proportion of 1 cwt. or 1½ cwt. per acre. Common salt, or quicklime, applied in the same manner, is said to be efficacious. The proper time for the operation is the spring, and on a damp or wet day, or immediately before or after a heavy rain. It is asserted that rape or linseed cake manure is fatal to these grubs.

The natural enemies of the cockchafer and its grub are the large species of *carabus*, especially the *carabus auratus*, which by attacking the females and killing them at the momemt of ovi-position, not only destroys the insect but prevents the birth of thousands of young grubs. The other enemies are pigs, moles, ravens, rooks, crows, and jackdaws, the wood-pecker, the bat, the badger, weasel, pole-cat, &c.



THE GERMAN OR FIELD COCKCHAFER.

(*Melolontha agricola*, Fabricius; and *anisoplia*, Köppe.)

This insect is rare in Britain. According to Mr. Donovan all the known examples have been found on the coast of South Wales. It feeds upon the ears of wheat and rye, and

when abundant, which in this country is seldom the case, it proves very disastrous. Köllar says that these insects are at times found in the month of June, three or four together on one ear, devouring the soft grain of rye, or of wheat, one third of which have thus been destroyed by them. According to the same authority, crows, moles, and field-mice, are its greatest natural enemies, and when their number is great, the above animals should be spared.

Hand-picking is the only artificial method of subduing the numbers of the perfect insects; after collecting them they may then be destroyed by pouring boiling water upon them, or by giving them to poultry, which are very fond of and fatten upon them. The best time for searching after these insects is, as for the cockchafer, early in the morning or during the heat of the day.

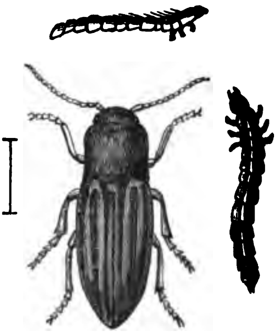
SLUGS (*Limax agrestis*).

Slugs sometimes cause considerable damage in cultivated lands, and they are too well-known to require particular description. They are of a red or black colour, and generally are found in damp or cool places. In winter they burrow into the ground, where they remain in a torpid state, but during spring and summer they come out and devour all kinds of tender plants, and are on that account very injurious to young crops. During the day they retire under stones or other sheltered places, for they cannot endure the heat of the sun, but in the morning and in the evening, or during the day after showers, and in cloudy weather they are met crawling about, gnawing the young shoots with much voracity, and thus doing great mischief. They begin to appear in April.

Various methods may be resorted to for the purpose of stopping or preventing the ravages of slugs; one of these methods consists in strewing the ground with coarsely pulverized oyster shells, the fragments of which being sharp and cutting, altogether oppose their progress. A mixture of slaked lime and ashes is said to produce the same effect, but as the application of lime is not suited to all soils, and slaked lime may prove injurious to some crops, it is preferable to use common salt, which kills them. In effect, if salt be sprinkled upon a slug, it immediately emits a very large quantity of very tenacious slime of a white and yellow colour, which becomes as thick as glue, and in a few minutes the slug swells, stiffens, and dies. Nitre produces the same effect. The proportion of salt per acre, according to Jacob Busk, Esq., should be from four to five bushels per acre, and the operation should be performed in the evening. Next morning a quantity of slime and of dead slugs will be found lying on the ground. This method is certainly cheaper and less troublesome than any other.

The natural enemies of slugs are fowls, ducks, geese, rooks, crows, jackdaws, jays, &c.; and as they crawl on slowly, they are easily devoured by these animals.

THE WIRE WORM.



(Grub of the lined click beetle). *Elater lineatus*, Oliver; *Cataphagus*, Stephens; *agriotes*, Eschscholtz.

This insect belongs to the family of the *elateridæ;* the body is oblong, the forehead and thorax are very convex, blackish, and covered with a greyish down, its length is about four and a half lines. Its elytra, or wing-cases, are of a fuscous colour, with longitudinal lines or striæ, somewhat raised, and rather lighter than the alternate depressions. The under part of its body and its legs are blackish.

There are however, upwards of sixty species of this insect in Britain, and it is probable that a considerable portion of them feed upon our most valuable cultivated lands.

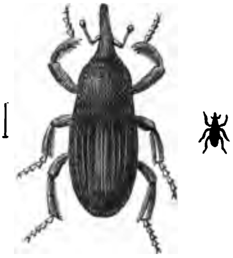
The wire-worm is the larva or grub of this insect; when full grown it is about seven lines long, and rather less than a line in breadth, of an ochre yellow colour, except the anterior part of the head, which is brown. The body is nearly cylindrical, covered with a hard crust, which communicates to the worm an uncommon degree of hardness, from which circumstance it derives its name. The body is composed of twelve segments or rings, closely jointed, smooth, with only a few scattered hairs, and six conical scaly legs are placed in pairs, on the three segments near the head, the last segment, however, consists of a fleshy tubercle, which answers the purpose of a seventh foot. This fleshy part has two brown points or dots, which, it is surmised, may assist in respiration. The animal remains in the state of larva, or wire-worm, during five years before it becomes the perfect insect; and, during this long period, it lives indiscriminately upon the roots of wheat, rye, oats, and every kind of grass, and likewise upon carrots, turnips, &c., thus causing sometimes considerable damage. The worm abounds chiefly amongst newly-cleared soils, or broken-up old pasture lands, and it is calculated, that in such soils the amount of its depredation averages one-twentieth part of the seed sown therein; which, for England only, represents a sum of at least £ 24,000 annually. (See the *Quarterly Journal of Agriculture*, vol. viii. page 101.) The wire-worm always lives beneath the surface of the soil, and in every plan suggested for their destruction, this circumstance should therefore be kept in mind. Wherefore applications of quick-lime, soot, and other substances, which lie on the surface of the soil and do not, or only to a trifling extent, penetrate it, have proved perfectly useless; and, on the other hand, the remedy applied should be such as to be poison to the insect but not to the plants, or else the remedy may prove worse than the evil.

The best way of destroying these insects is, according to Bjerkander, to plough up the ground frequently, and to cause children to follow the plough and pick up all the worms that may be turned up. Crows, rooks, magpies, and other birds, being very fond of these larvæ, will also do considerable execution amongst them.

The wire worm being very fond of the potato, Sir Joseph Banks proposed a very simple plan for their extermination, which plan consists in sticking slices of potatoes upon skewers and burying the whole; the worms soon fasten upon these slices in preference to other plants, and on withdrawing the skewers, which should be done every day, the wire-worms are thus easily collected and destroyed.

THE CORN WEEVIL.

(*Calandra granaria*, Clairville; *curculio granaria*, Linnæus.)



This small insect, one of the most injurious to corn in granaries, is of a uniform brownish or pitchy black colour; its legs and antennæ are rusty red, and its length is barely two lines. The thorax is besprinkled with small oblong punctures or cavities, its elytra, or wing-cases, are striated, but it has no wings under them; its abdomen is large and also punctured, its legs are powerful, its mouth is small, but provided with a cylindrical, sharp, and pointed trunk or rostrum, at the basis of which the antennæ are placed, the whole forming, as it were, three prongs, of which the rostrum is the middle one. The insect is sluggish, and if any thing occurs to frighten it, it immediately gathers up its legs and antennæ under its body, in which state it greatly resembles a grain of corn.

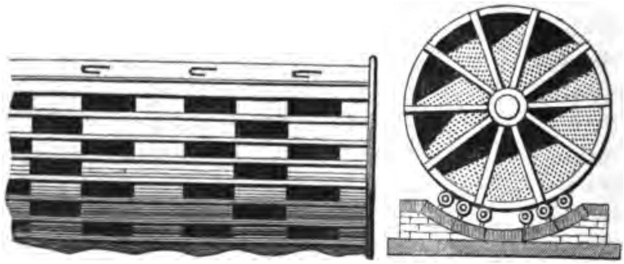
The corn-weevil, like most other insects, exists in four distinct states; namely, in the state of egg, of grub, of pupa, and of imago. One of the eggs only is deposited on each grain (for one grain could not support more than one larva), always in the groove of the grain and at the top, or very near the germ where it is fixed, and covered over with a gummy matter; the egg is too small to be seen by the unassisted eye. In the second state the insect is a soft, oblong, and very white larva or grub, nearly one line in length, and which in the course of two, three, or eight days, according to the temperature, issues from the egg, and piercing the fine skin of the corn at that part where the egg is glued, as above said, penetrates into the grain; about twenty days after, the whole of the farina is devoured, though the seed or grain retains its usual external appearance, and looks perfectly sound. From the state of grub the insect passes into that of white transparent pupa, or crysalis, during which stage the insect does not consume food, but after having thus remained motionless for twelve or fifteen days, the pupa is transformed into the perfect insect which emerges from the grain, and at once begins its destructive work by gnawing the outside of the corn, and after pairing, deposits eggs upon the grains. The male insect dies one day after pairing, and the female one day after laying her eggs. The ravages produced by this insect are sometimes prodigious, it has been calculated that the generation of one single female insect destroys, in six months, from April to September, 6045 grains of wheat.

As the larva lives in the interior of the grain, it is almost impossible to destroy the insect at that period, but when the insect has become perfect, the various operations to which the grain is subjected often kill the animal or compel it to flee away. The corn weevil being fond of darkness, of warmth, and of rest, it is evident that a well lighted, and well ventilated granary, on the one hand, and the operations of sifting, and winnowing, or of frequently tossing the grains about with a shovel, on the other, powerfully contribute to its destruction. But in order that the mischief may be alleviated or removed by these operations, it is absolutely necessary that the floors, the ceilings, and the walls, be in a state of good repair, in order that the weevil may not take shelter in some corner or crevice.

Numerous methods have been proposed for destroying the corn weevil, but a few only have proved efficacious. Fumigations with tobacco, and other odoriferous, or acrid plants, with deleterious gasses, such as sulphurous acid, ammonia, sulphuretted hydrogen, oxyde of carbon, &c. sprinkling with essence of turpentine, or with decoctions of fœtid herbs, have been tried, but all with indifferent success. Another process, which is more economical, more simple, and which is said to give good results, consists in placing by the side of the heap of wheat infested with corn weevils, another small heap of corn (preferably of barley, of which corn weevils are still more fond than of wheat), and the heap of corn is then vigorously tossed about. The greatest number of the weevils satisfied with the serving of this first notice to quit, leave the heap and take refuge in the undisturbed barley; the operator after some time repeats the treatment, and again leaves the whole at rest. After four or five days of such rough handling, it will be found that the weevils have altogether removed to the quieter home offered to them by the heap of barley; but whilst they are probably rejoicing at having found such quiet, comfortable quarters, with a choice banquet, the farmer puts a stop to the feasting by pouring boiling water upon the luckless and decoyed guests in sufficient quantity to soak the heap of barley. This process should be resorted to at the beginning of the spring, before the weevils have laid their eggs.

In 1836, M. Vallery contrived an apparatus, called a moveable granary (*grenier mobile*), which, it would appear, gives the most excellent results.

This apparatus (see the figure) is a large cylinder constructed in open work, and which turns horizontally upon its axis. The external part consists of staves, strongly bound together by iron hoops, symmetrically perforated, and covered with wire-gauze, through which the air finds admittance into the cylinder, whilst at the same time they serve as so many issues for the exit of the insects. The bearings of the cylinder are properly insulated, so that the insects may not re-enter the cylinder, and to these bearings a light roof is attached, provided with a small gutter running all along the edge, and which is filled with oil. The object of the roof is to guard against any of the insects which might have crawled to the ceiling, falling upon the moveable granary when at rest and thus re-entering it.



The apparatus should not be entirely filled with corn, for otherwise the grains would remain at rest whilst the cylinder is rotating. The cylinder being set in motion, a centrifugal ventilator is applied to one of its extremities, which aspirating the air contained in the cylinder, compels the external air to replace the vacuum produced, and thus a thorough ventilation of the grain is effected. In order to reduce the power which would be required to work this machine, it is symmetrically divided into a number of partitions or chambers (see fig. p. 180). The axis is hollow, and it is through it that the air aspirated by the ventilator escapes. The chambers equipoizing each other, an economy of above 28 per cent. is obtained in the power which would otherwise be required to work the apparatus, whilst at the same time, the surface of the grain being thereby multiplied, a thorough ventilation is secured.

Experiments on a large scale, performed with that apparatus by order of the Ministre du Commerce, upon 120 hectrolitres (about 397 bushels), proved that after keeping the apparatus in motion for forty-eight hours, only twenty weevils remained in the fifteen hectolitres (about forty-nine bushels), contained in one of the eight partitions of which the cylinder consisted, and which were infested with 37,950 corn weevils. This great number of insects had thus been compelled to desert the grain, and were, for the most part, found against the walls of the shed. Mr. Vallery's apparatus is also eminently useful to ventilate and dry damp corn.

A single man is sufficient to set in motion an apparatus containing 1000 hectolitres (more than 3000 bushels), and as each revolution of the cylinder is equivalent to one ordinary shovelling, there is an economy of labour in the proportion of 1 : 56.

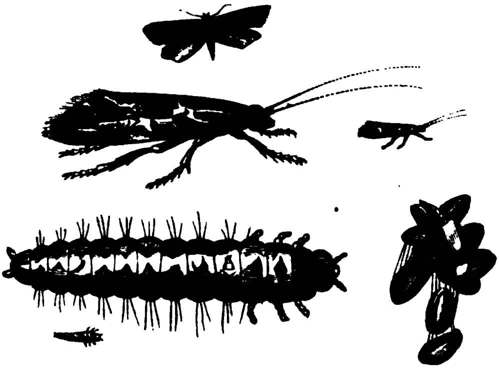
The moveable granary answers equally well for all sorts of grain and seeds.

From the *Cours élémentaire d'Agriculture*, by Messrs. Girardin and Dubreuil, the principal facts concerning this insect are extracted.

The above apparatus, of a size capable of containing 1000 hectolitres of corn (about 3300 bushels), costs 6,600 francs (£264). The average price of an ordinary granary of the same capacity, is estimated at 8300 francs (£332), which would realise a net economy of 25 per cent., as the difference between the cost price of the improved revolving granary and those in ordinary use.

THE CORN MOTH, OR CORN-WORM.

(*Tinea Granella*—Linnæus.)



This insect belongs to the order of *lepidoptera*, or butterflies, and its larva or grub is, next to that of the corn weevil, the most destructive in granaries, and especially those situate on the banks of the Thames, in the vicinity of Rotherhithe, &c., where it commits incalculable havoc among the grain.

The anterior wings of the perfect insect are of a livid hue, varied with brownish black and white spots, of dissimilar forms and sizes, the latter approximating to the black; cilia ashy-white, varied with brown; posterior or hind wings, deep leaden black, ciliarat her paler, forehead white. It is very abundant throughout the metropolitan districts during the summer, especially in July and August. (Stephens' *Illustrations of British Entomology,*" Vol. IV.) It is very sluggish during the day, but when night comes it flies about for the purpose of pairing, &c.

The presence of the larva or worm of this insect is detected by a whitish grey web, which binds several grains together (see fig. above), amongst which small whitish dots may be observed, which are the excrements of the insect.

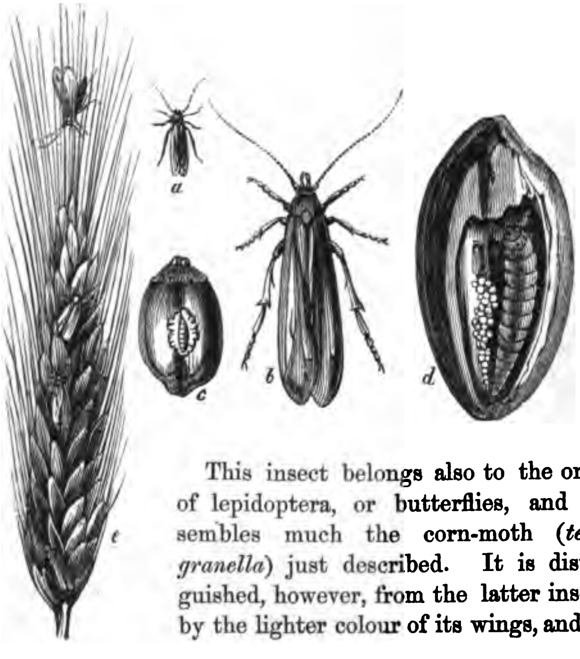
If now the grains be taken asunder, it will be seen that some are partly gnawed, and possibly the small worm may be found in one of them. The white roundish excrement hides the hole through which the insect has penetrated the grain. When the larvæ are full grown, and ready for their change into the pupa state, which takes place about August or September, they desert the grains, climb up the walls, joists, and boards, and taking position in every crack or corner, they suspend themselves by the posterior part of their body, spin a sort of cocoon, and soon become transformed into the pupa state. Towards March, or April, or May, the moth or perfect insect comes out of its case, and takes its quarters in the darkest corner of the granary, where it remains hidden during the day. The moth never leaves the granary. During the state of pupa and of moth the insect does not feed at all, it is only the larva, grub, or worm which destroys the grain, and it feeds not only on wheat, but likewise on rye, barley, and oats, the damage thus done being sometimes very considerable.

The best method of destroying the insect is to toss up or move the grain about whilst the insect is in the worm state, which, as we said, occurs in the months of May to August. The web which binds the grains together being broken by that operation, the larva is left exposed, and is crushed between the grains during the operation.

The moveable granary of which we have been speaking, in the preceding article, answers the purpose equally well for preserving the corn from this insect as from the corn-weevil. Hand-picking at the time when the larva deserts the grain and is climbing along the walls, may also be resorted to, at that epoch a vast number may thus be speedily destroyed. It is also a good precaution to sprinkle the floor with a mixture of strong white wine vinegar, or pyrolignous acid and common salt, before warehousing the corn in the granary. The walls and the floor should be carefully swept and cleaned before-hand, and every cocoon which may be found must, of course, be summarily disposed of. The sweepings should be immediately carried away and thrown into the fire, for if they be not removed at once, the insect will crawl out, and the trouble taken will have been in vain. But the best remedy, as we said at first, is thorough ventilation. Kiln-dying may also be resorted to, since a temperature of 19° Reaumur is sufficient to kill the insect; but this process is only applicable to such corn as is not intended for sowing, for the germinating power is thus destroyed. The corn-moth and the corn-weevil are always found together.

The natural enemies of the corn-moth are spiders, bats, and the small birds which feed on insects.

ALUCITE (*œcophora granella*, Latreille.)



This insect belongs also to the order of lepidoptera, or butterflies, and resembles much the corn-moth (*tenia granella*) just described. It is distinguished, however, from the latter insect, by the lighter colour of its wings, and by the absence of the transverse brownish streaks or spots which characterize the other insect, and also because it has two little *palpi* or feelers situated between the *antennæ*.

The larva only of this insect is injurious to corn, and it resembles very much that of the corn-moth in point of size and of form; it penetrates into the interior of the grain after spinning a very fine web, devours all its farina, and remains hidden within the grain until its metamorphosis into a butterfly is complete, so that the grain which has been attacked by that insect is always found to contain either the grub or the chrysalis, or the skin of the latter. Shovelling, tossing up, or otherwise stirring the grain is ineffectual in driving the insect away.

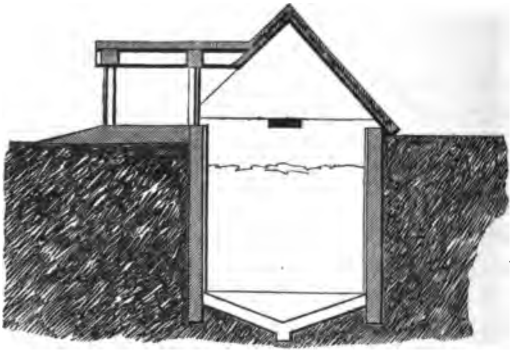
The presence of the insect in the grains is detected only by their diminished weight, and, when the insects are very numerous, by the great heat which the corn speedily acquires, and which generally precedes the exit of the butterflies. The grains are not tied together by a web, as is the case with the corn-moth. The butterflies of the alucite do not remain or dwell in granaries, unless the latter are very cool, they fly away, and infest the fields on which cereals, but especially wheat, are growing, and towards the evening they may be found laying their eggs on the ears. (See the fig. in the preceding page).

Duhamel, Tillet, and Hasard have ascertained that these insects may produce several generations in the course of the year, that they deposit their eggs both upon the grains stored up in granaries, and upon the ears in the fields, and that the eggs may hatch, and the grubs penetrate the grains both in the dry or in the green state.

Various methods of destroying this insect have been tried, but most of them are either inefficacious, or hazardous, or costly. It has been proposed to pass the corn rapidly through a large cylinder or roasting machine, heated to 100 or 110° Fahr., which temperature is sufficient to destroy the insect; but such a method is attended with too much risk, since, should by accident the roasting apparatus reach 140 or 150° Fahr. the corn would be damaged. The expense, besides, of that method is considerable.

Another method consists in placing in the granary a cask upon trestles, and introducing therein through the bung several thick pieces of calico impregnated with brimstone and inflamed; the cask being filled with the fumes of the burning brimstone, the corn should be poured into it by means of a large funnel or hopper, until quite full. The cask is then bunged up, and after a little time it is rolled out to the bin or store-room, and emptied through the bung. With two such casks, into one of which alternately the sulphurized match is kept burning, whilst the other is being filled with grain, a very large quantity of corn may be purified.

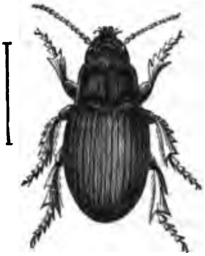
Another method consists in erecting a granary constructed on the principle of an ice-house, in which the temperature, remaining uniformly at 50° Fahr. prevents the hatching of the eggs of the insects.



This form of granary, invented by M. Demarçay, is effective also against the corn-weevil, and the cost of erection of such an apparatus capable of holding 3300 bushels of corn (1000 hectolitres) is estimated at £132.

THE GIBBOUS GROUND BEETLE.

(*Carabus gibbus*, Fabricus; *zabrus gibbus*, Clairville; *Harpelidus tardus*, Latreille; *bupreste arotofago*, Corti.)



The gibbous ground beetle is of a pitchy and glossy black colour, with a brassy hue, and a remarkably convex body and thorax, antennæ and legs pitchy.

This insect feeds indiscriminately upon all the other insects and grubs which are less powerful than itself, and as such it is altogether a friend instead of a foe, for it thus helps in keeping the noxious species of insects within limits. Its larva, however, has been accused of destroying young wheat and Köllar, in his *Treatise on Insects*, &c., gives a long account of the devastations which it caused in the year 1812 in the corn-fields in the Canton of Seiburg, near Halle, in Germany, 230 acres of which were destroyed by it. It is stated that these larvæ were first observed in a wheat-field which they destroyed, and wheat having again been sown, they destroyed it again. Afterwards they devoured rye and after that barley; but as in the account of the insect given by Germar in his first volume of his *Magazine der Entomologie*, it is stated that the larvæ of this carabus were accompanied by about one-fourth of the larvæ of the cockchafer, it is possible, says M. Stephens, that they rather fed upon the latter, to which the mischief done is attributed. And is it not probable, continues M. Stephens, "that the perfect insects ascend the corn for the purpose of devouring the insect parasites thereon? This is a subject that requires investigation, as it is highly important for the interests of the agriculturist in those districts where the insect abounds, that the question should be thoroughly set at rest, because, should the zabri depart from the habit of the group to which they belong, and become herbivorous instead of carnivorous, their destruction would be desirable; while, on the contrary, if they destroy the devourers of our produce, their preservation should be attempted. It may be added that certain specimens of the perfect insect, which were enclosed in a box with some corn, were observed to devour the latter so long as the supply lasted, when they attacked each other. But was not that analogous to the natural antipathy which animals seemingly have to feed by choice upon their own species? For it is a fact, which has been frequently observed by others as well as by myself, that if a quantity of carabideous insects of different kinds be confined together, the more powerful species will first attack those of the other genera, then such as are congenerous, and finally, when compelled, their own species." To these surmises Mr. Westwood opposes the testimony of the Rev. G. T. Rudd and of another gentleman, who distinctly perceived several specimens of zabrus upon the ears of corn, opening the husks and extracting and devouring the grain, from which it would appear that the zabri belong to a class of carnivorous insects, but that they constitute a group living upon a mixed diet of animal and vegetable food.

The perfect insect is found generally in corn fields, frequently on the ears of the corn itself, in the autumn, throughout the southern parts of the kingdom; it was found in plenty near Worthing, in 1817, and near Brighton the following year. In September 1827, it existed in profusion near Hastings; it occurs every autumn regularly and plentifully in the open corn lands about Cambridge. (See *Stephens' Illustration of British Entomology* — "*Mandibulata,*" vol. i. page 140.)

The larva of the ground beetle, when full grown, is about one inch in length, and it consists of twelve rings or segments, exclusive of the head, which is flat and covered with fine hairs; its antennæ have four articulations, and its mouth is provided with two long mandibles in the shape of forceps; it has three pairs of legs attached to the first three segments, which segments are brown on the upper and white on the under surface, with a brown spot on each side where the respiratory hole is situated. The other segments are yellowish-white, and have each two protuberances or warts, and thin bristles on each side.

The pupa is of a yellowish-white colour, the palpi and legs are folded on the corslet and the abdomen; it has a delicate and transparent skin, so thin that the slightest rough usage bursts it.

Of all the insects which commit depredations in agriculture, none, says Giuseppe Gené, is more destructive, and therefore deserves more to be known and persecuted.* These insects pair at the beginning of September or thereabouts, and in November or October their eggs are hatched, and the larva immediately begins to feed upon the young shoots of wheat, but at the beginning of winter they cease eating and sink into the ground, and emerge again at the beginning of spring, or even during the winter days which happen to be sufficiently warm, the worm rising or sinking at will through the cylindrical hole which it has excavated, and which is always in the vicinity of a corn-field, or in the field itself. It seizes one of the leaves with its mandibles, draws it into its hole, and devours all the cellular substance thereof, which is found agglomerated near the stalk. Another leaf is treated in the same manner, and thus in a short time all the parenchymatous substance of the leaves of the blade is absorbed, in consequence of which the roots and the untouched parts of the young shoot which remain under ground are much injured. Having thus destroyed one or more of the shoots, the worm removes to other lodgings near other plants, which it treats in the same manner; it is never found upon the ground during the day. The larvæ or grubs, are so greedy and voracious, and so over gorge themselves with the cellular substance of the leaf of the young sprouts, that when drawn from the earth they emit by the mouth a liquid juice, of a dark green colour, which is nothing else than the above-mentioned substance, with which they are filled almost to bursting. When first gathered from the ground they are comparatively torpid, but in a short time they pluck up courage and move with agility in order to hide themselves.

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* Sugli insetti più noscivi alla agricoltura dal dottore Giuseppe Gené.

Like all larvæ, those of the ground beetle change skin several times before they attain their fullest size, pending which they cease eating, and remain hidden; the damage caused is diminished in a notable manner, but the skinning once over they fall to with renewed vigour, and the devastation proceeds rapidly. At an advanced stage, and when the larvæ are robust, they prefer the old to the young and tender shoots. Having at last attained their greatest development, which happens towards the end of April, or the beginning of May, they sink into the ground, and scoop out a cell of an oval form and pass into the state of pupa.

Although ordinarily the pupa becomes converted into the perfect insect towards the end of May, it is not seen above ground before the middle of June. Like the larva, it dislikes light, and during the day remains concealed under clods of earth, stones, &c., whence it emerges only when the sun sets, at which time the insects climb up the stalks of wheat, and devour the grain. During the harvest, they also climb up the sheaves and hide themselves underneath, thus continuing, in the state of beetle, the devastations which they began in the state of larva. (See Bonaventura Corti, *Storia naturale di quegli insetti che rodono le piantine del frumento in erba.*)

The best means of destroying these insects are the following:—

To look for the insects during the day under stones and other sheltered places, and to pick up all those which may thus be found. Also to procure a net similar to those which are used for catching butterflies, and to skim the ears of corn with it during the night, so that all the beetles which may be then feeding on the ear may fall into the next. The beetle may also be found early in the morning upon the sheaves devouring the grain. Deep ploughing late in autumn, of such fields as may have been infested will bring up the larvæ which had already retired to their winter quarters, and being thus turned up, exposure to the cold will kill them, or they will be devoured by crows and other animals.

THE COMMON DART MOTH.

(*Agrotis affinis*, *agrotis segetum*, *noctua segetis*, Linnæus.)

This insect is extremely common, and appears in June or July, and its caterpillar is extremely destructive to young wheat, and buck-wheat in May. This caterpillar is found at the root of corn, it is of a dingy brown colour, with a pale dorsal and lateral line, the latter with a reddish tinge and black dots. Mr. Westwood says that this caterpillar is also very troublesome in gardens where it often destroys anemones and other flowers, and eats the roots of dahlias, &c. It is also the larva of this, or one of the closely allied species, which often injures the turnip crops in the autumn to a very great extent in different parts of the country. (See Westwood on *British Moths*, vol. i., p. 116). This larva abounds sometimes in certain districts in alarming numbers, and commits incredible ravages; for, like the grub of the cockchafers, it devours the roots of the young corn, leaving the leaves or blades untouched, so that the mischief is not at first apparent. The caterpillar passes into the state of pupa towards the end of May.

The perfect insect or moth is, as the rest of the genus, extremely variable, scarcely two specimens being found precisely similar. The fore wings measure about two inches, they are of a brown colour, or sometimes nearly black, and its length from the top of the head to the extremity of the wings measures eleven lines. When at rest the wings are folded flat over the body, the hind wind wings are of a bluish-white colour, with a purple tint, the hind margin and veins are dusky, especially in the female, which altogether is darker than the male.

The female moth deposits her eggs in loose ground, preferably in the soils which have been ploughed early, towards the middle or at the end of the month of August, and twelve or fourteen days afterwards they are hatched, and immediately the young caterpillar begins to eat, it attacks all sorts of tender grasses until the young shoots of corn begin to appear. When the cold season begins they descend into the earth, and at a depth of two or three inches they excavate a small oval cavity into which they retire for the winter during which time they do not eat, but when spring comes they emerge from their recess, and again begin to feed on the roots of the young corn and grass. It is found in the day time under stones, leaves, clods of earth, or other situation sheltered from the light.

The destruction of this insect in either of its states is attended with considerable difficulty. A good way of effecting this object is to plough the soil early, and to sow as late in the season as possible, for the deposition of the eggs taking place generally, as we said, in those soils which have been ploughed early, and the hatching, twelve or fourteen days afterwards, it is evident that by differing the sowing a few weeks, the eggs will be hatched, and the young caterpillars will then die for want of food.

Another method which is said to answer well, consists in pickling the grain to be sown in the manner described page 38, which process besides will at the same time act as a preventive to the attacks of various fungi, as mentioned before.

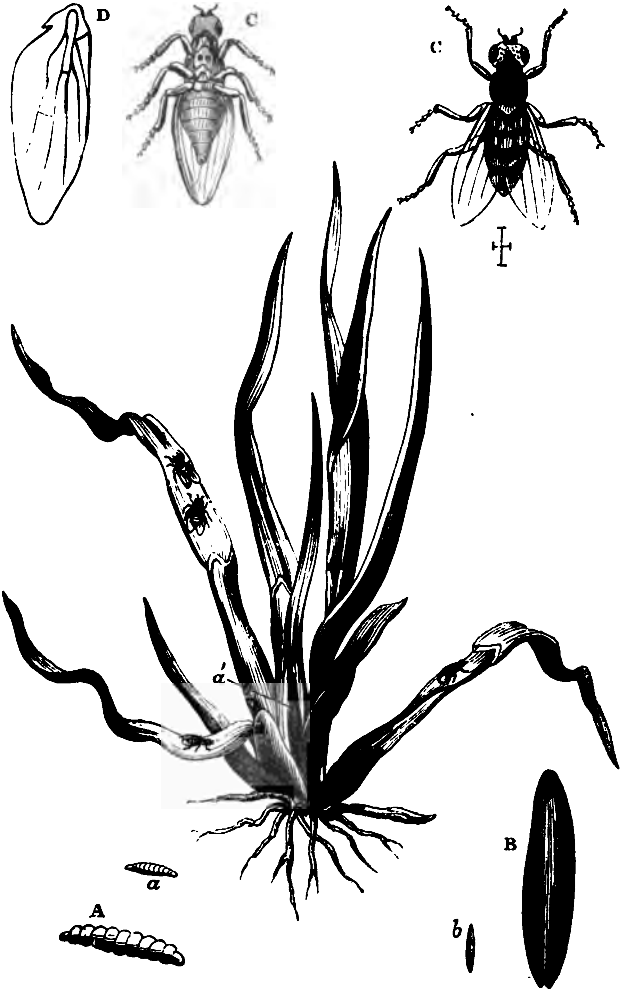
Another method is hand-picking. The insects must be looked for during the day under stones, clods of earth, &c., and after sun-set, or even during the night, if need be, the search may be continued with the help of lanterns, for at that time the insects come out to feed, and may be then gathered in very large numbers.

The natural enemies of this moth and caterpillar, are the same as those which feed upon other moths and grubs, namely, crows, jack-daws, rooks, magpies, moles, mice, &c.

THE WHEAT FLY.

(*Chlorops pumilionis*, Mugen; *Musca pumilionis*, Bjerkander; *Oscinis pumilionis*, Fabricius.)

a	The caterpillar, of its natural size, as it is found in the centre of the green wheat, just above the root.
A	The same magnified.
B	The same magnified.
c	The fly of its natural size.
C	The same magnified.
D	The wing magnified.



This fly, which, early in the course of the spring of the year 1790, in the neighbourhood of Battle, caused much damage to young wheat, and being confounded with the Hessian fly, created considerable alarm amongst farmers, is of a black colour, the under part of the head is yellow, and the thorax is marked with two lines of the same colour, the halters are white, the legs are ash-coloured, and their extremities black.* A most excellent account of this fly, by William Marwick, Esq., F.L.S., with additional remarks by T. Marsham, Esq., Sec. L.S., having been read at a meeting of the above learned society, the 1st of November, 1791, and printed in the 2nd vol. of their Transactions, we beg to reproduce it here:—

" Early in the course of last spring some fields of wheat, in the neighbourhood of Battle, appearing to be much blighted, a friend of mine discovered it to be caused by a small insect of the grub or caterpillar kind, lodged in the centre or very heart of the stem, just above the root. About the latter end of March (1791), I procured some of the wheat, examined it, and found in most of it a small larva or caterpillar alive, but in some it was already changed into the chrysalis state.

"Being exceedingly anxious to determine the species of this apparently destructive animal, I planted some of the diseased roots in my garden, under a hand-glass, where they flourished very much, and threw out strong shoots on each side (the middle shoot withered); but whether the flies escaped through some hole in the glass, or whether they were devoured by a colony of ants, which made their nest under the glass, I cannot tell, as I did not succeed in this attempt; for when I pulled up the wheat and examined it, there was an empty chrysalis in each plant. However, I had better luck in my next attempt: I placed several of the diseased roots of the wheat in a small flower-pot, filled with bran, and covered it over close with gauze, in such a manner that no insect could get in from the outside, nor could any escape from within. On the 14th of May (1791), three small flies were discovered, sitting in the inside of the gauze on the young wheat, as represented in the figure. A few days after three more of the same flies appeared. There were in the flower-pot of bran six roots of diseased wheat, which produced six flies: on examining the roots afterwards, I found an empty shell of the chrysalis in each, so that I think there is no doubt of the identity of the insect in question.

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* Muscæ pumilionis nigra subtus capite, thoracisque duabus lineis flavis, halteribus albis, pedibus cinereis, apice nigris.—Gmelin's *Systema Naturæ*.

"I mentioned that the larva and chrysalis were always found deposited on the principal stem just above the root. This stem it invariably destroyed, which gave the crop a most disastrous appearance, so that there was scarcely a hope of any produce; but after the larva had changed into its chrysalis state the mischief ceased, and the root was not so materially injured as to prevent its throwing out fresh shoots on each side, or stocking itself, as the farmers term it, as I experienced by those which I planted in my garden.

"In short, at harvest-time I was most agreeably surprised to find a good crop of wheat, and the ears large and fine throughout the whole field. My friend thinks it the best crop on his farm, and supposes he shall have about three quarters and a half of threshed corn for each acre.

"During my observations upon this insect, a variety of thoughts suggested themselves to my mind. It was hinted to me that possibly this was what has been called the Hessian fly, whose depredations in America have been so notorious. If so, a little good English husbandry, by keeping the ground in heart, and thus enabling the wounded shoots to repair themselves by strong lateral ones, prevents our being alarmed to so great a degree. I had my doubts how and what time the egg of the caterpillar was introduced into the field; it was imagined it might have been carried on in the manure, but the only manure applied to this field was lime, and I do not understand that to be the receptaculum of any of the genus musca. The kind of wheat sown was a white wheat, lately introduced here from Surrey; my friend could not recollect with certainty its name, but thought it was called white Zealand wheat. None but what was sown early, about the latter end of September or the beginning of October, was affected by this insect; and in one field where a part was early sown with white, and the other with red wheat at the same time, the white wheat was much affected, and the red but very little. The reason why the early sown wheat only was affected is, I should imagine, because the cold of the approach of winter destroyed the fly before the late sown wheat was springing out of the ground, consequently it could not lay its egg in that."

The explanation of the figure has been given at the beginning of this article.

"In addition to the foregoing accurate and valuable observations of Mr. Marwick," said Mr. Marsham, "it may not be improper to observe that the larva of this fly was sent several months since, with some of the roots of wheat that were attacked, to Arthur Young, Esq., who being apprehensive that they were the larva of the Hessian fly, sent the roots of wheat to Sir Joseph Banks, enclosed in a glass phial, for his opinion. Upon examination it was found that the insect was still in the stem or principal shoot of the plant, in its pupa state. These being carefully preserved, the fly appeared in a few days, and Sir Joseph Banks determined it to be the musca pumilionis of Gmelin's *Systema Naturæ.*"

An account of this fly and its destructive properties was first published in the "Transactions of the Royal Academy of Sciences at Stockholm for the year 1778, by Mr. Ol. Bjerkander," who discovered it on the young shoots of the rye in the month of May, at the lowermost joint, which stopped the growth of those shoots, and made them appear as dwarfs, which circumstance suggested the name of pumilionis. He describes the larvæ to be white, two lines in length, composed of ten rings, the head pointed at the end, black, and resembling a V. They passed into their pupa state the 25th of the same month. The pupa was yellow, shining, rather more than one line in length, and composed of rings. The flies appeared the 12th of June and the following days; the perfect animal is well described above.

At what time these eggs are deposited in the rye is not yet determined. The larvæ were small on the 23rd of April, and full grown the 25th of May; on the sides of the stems were seen no holes, whence he conjectures that the eggs or larvæ must enter at the top of the leaves. The fly, when hatched, forces its way upwards, and flies out of its nest.

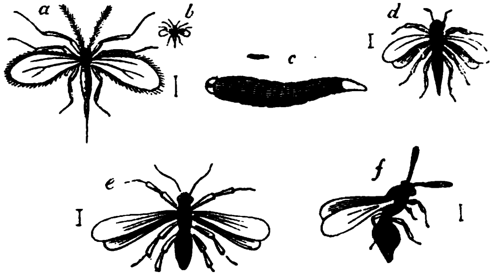
The dwarf stems, Mr. Bjerkander observed, began to grow yellow and decay the 14th of June, and were in such abundance, that in some fields, eight, twelve, or fourteen were found in a square of two feet, whence he concludes that great injury is done to the rye, and strongly recommends that the stems should be pulled up and burnt, while the insect is in the larva or pupa state; and by this means he thinks one or two persons might destroy many thousands of them in a day, he himself having picked up 350 stems in a few hours.

It will certainly be a pleasing satisfaction to the public in general, and to the farmer in particular, to know that this insect is not the Hessian fly of America; and also from the careful experiments of Mr. Marwick, to find that its destructive properties are not of that magnitude as were at first apprehended, or as Mr. Bjerkander supposed; though perhaps an increase of the fly may render it a formidable enemy.

From the foregoing observations of Mr. Marwick, that the diseased plants, instead of being lost, produced a number of lateral shoots, and the crop in the field of wheat in which the fly had made some havoc turned out exceedingly well, it follows that Mr. Bjerkander's advice of picking up and burning the stems that are infested, would be highly prejudicial; but perhaps pinching the central leaves just above the crown of the root, where the insect is usually found, might effectually destroy it, and leave the plant in a state to throw out its lateral shoots.

THE WHEAT MIDGE.

(*Tipula tritici*, Kirby—*Cecydomia tritici*, Latreille.)



a tipula tritici magnified—*b* the insect's natural size—*c* magnified larva of the tipula, and the same larva natural size—*d* Ichneumon inferens magnified; the line indicates the natural size—*e* Ichneumon tipulæ magnified; the line indicates the natural size—*f* Ichneumon penetrans magnified; the line indicates the natural size.

This extraordinarily small insect (the wheat midge) is of a deep orange yellow colour, the wings are beautifully clear and iridescent, fringed at the edges, the eyes are black, the antennæ longer than the thorax, and moniliform or necklace shaped.

According to the celebrated naturalist the Rev. W. Kirby, who published in the fourth and fifth volumes of the Linnean Society, two most valuable and interesting papers on the history of this insect, it appears that the little creature does not make its appearance before the spring, at which epoch it deposits its eggs by means of a very long retractible tube, or vagina, which unsheaths an *aculeus*, or sting, which the insect introduces into the floret upon the interior valvule of the corolla, just above the stigmata, so that the larva is hatched about the time when the wheat is going to blossom, and the larva probably devouring the pollen, or dust of the antheræ, fructification is prevented, and the harvest of course destroyed to a greater or less extent. The larva has no feet, and is of a lemon yellow colour, with little warts on the sides, and jumps upon being touched, the pointed part represented in the figure is the head of the larva.

The perfect insect is very active in the evening, towards the end of May or beginning of June; to the end of the latter month they may sometimes be seen in wheat fields flying about in all directions, and in countless numbers. From seven to nine o'clock the fields swarm with them at times, but at the latter hour they generally disappear. Mr. Kirby says, that on one occasion, on the 3rd of June, having had to pass through a field planted with wheat, the insects were so extremely numerous, that if each of them were to lay its eggs in a different floret, and those eggs were permitted to produce larvæ, more than half of the grain, upon a moderate calculation, would be destroyed. He noticed twelve at one time depositing their eggs in the same ear. "Although these insects are so numerous in the evening," says Mr. Kirby, "yet in the morning not a single one is to be seen upon the wing; they do not however quit the field which is the scene of their employment, for upon shaking the stalks of the wheat, or otherwise disturbing them, they will fly about near the ground in great numbers. I found their station of repose to be upon the lower part of the culm, with their head upwards."

"The pupæ bear no proportion to the number of larvæ. I have seen more than once seven or eight florets in an ear inhabited by the latter, and sometimes as many as thirty in a single floret, seldom less than eight or nine, and yet I have scarcely ever found more than one pupa in an ear, and had to examine several to meet with that." It is probable that they are destroyed by still smaller insects, called ichneumons, which being often mistaken for the injurious midge, bear all the odium of the devastation produced; they are however, the best friends of the farmer; to them the prevention or attenuation of the mischief which would otherwise be done, is due, and it is providentially so; for when we consider, on the one hand, the extreme smallness of the wheat midge in all its states of egg, of larva, and of nymph; on the other hand, the fact of the devastation taking place in the ear only when in blossom, it is clear that but for these ichneumons, their natural enemies, the loss which amounts to $\frac{1}{20}$ of the produce would be very considerable, since no remedy whatever, or scarcely any of an available kind, could be resorted to. "To see the little ichneumon deposit its egg in the caterpillar of the wheat fly," says M. Kirby, "is a very entertaining sight. In order to enjoy this pleasure, I placed a number of the latter upon a sheet of white paper, at no great distance from each other, and then set an ichneumon down in the midst of them. She began immediately to march about, vibrating her antennæ very briskly; a larva was soon discovered, upon which she fixed herself, the vibratory motion of her antennæ increasing to an intense degree, then bending her body obliquely under her breast, she applied her anus to the larva, and during the insertion of the *aculeus*, and the depositing of the egg, her antennæ became perfectly still and motionless. Whilst this operation was performing, the larva appeared to feel a momentary sensation of pain, for it gave a violent wriggle. When all was finished, the little ichneumon marched off to seek for a second, which was obliged to undergo the same operation, and so on to as many as it could find to which no egg had been before deposited, for it commits only one single egg to each larva. I have seen it frequently mount one which had been pricked before, but it soon discovered its mistake and left it. The size of it is so near that of the tipula, that I imagine the larva of the latter would not support more than one of the former, and therefore instinct directs it to deposit only a single egg in each; besides by this means one ichneumon will destroy an infinite number of larvæ."

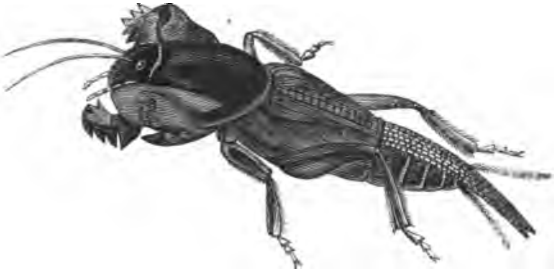
It is probable that there are no less than three ichneumons which destroy the wheat fly; they are represented in the figure, their body is black as well as their legs, except those of the ichneumon tipulæ, which are of a reddish yellow colour.

One of the remedies proposed consists in not sowing wheat again in the year following that in which the insect will have been predominant, either in the same field, or in the neighbourhood, for the pupæ, it is supposed, lie in the earth, the larvæ having descended therein from the ear to about the depth of half an inch, which accounts perhaps for Mr. Kirby's finding a deficiency in the proportion of the pupæ compared to that of the larvæ; Mr. Kirby, however, to whom this explanation of the disproportion occurred, seems to reject it, and to attribute the diminution of the pupæ mainly to the influence of the ichneumons.

Perhaps fumigations of tobacco or sulphur, made at the time when the wheat begins to ear, and when the wind is favourable, might prevent the insect from depositing its eggs upon it.

THE MOLE CRICKET, CHURR-WORM, JARR-WORM, EVE CHURR, EARTH CRAB.

(*Gryllus gryllotalpa*, Linnæus; *Gryllotalpa vulgaris*, Latreille.)



This insect is nearly allied to the family of the crickets, from which it differs, however, by the form of its fore-feet which are broad, resembling those of moles, and which they use in the same manner, that is for the purpose of excavating subterraneous galleries. Their eyes are small, oval, and of a lustrous brown colour, and like the ordinary cricket, they have the power of producing with their wings the well-known chirping sound. When full-grown the insect is about two inches long, and four lines broad; its colour is brown, and there are at the extremity of the body two long, soft, and articulated appendages, the use of which is not known. It has been surmised, however, that they may be tentaculæ, by which they may become aware of the presence of an enemy whilst engaged in digging. The insect is very powerful, considering its size; Cuvier and Buffon state that it can overcome a weight of three pounds, upon an even and level surface; and Rösel goes farther, for he asserts that it is capable of pushing forward a weight of six pounds with his fore feet on a smooth and level surface; it is certain, however, that whatever may be the extreme limit of the strength of the creature that it can pierce and excavate even compact soils with ease.

At the beginning of summer the female excavates for herself, at about half-a-foot from the surface, a burrow, having the shape of a Florence flask, two inches long, with a curved neck in communication with the surface, and having rendered the interior perfectly smooth, she lays from three to four hundred elongated eggs, of a yellowish-brown colour, shining, and about the size of a millet seed. About one month afterwards the eggs are hatched, and are at first completely white, but in proportion as they grow they become grey, and then brown like their parents; they then disperse into field and gardens, committing sometimes great havoc, their presence being indicated by small hills of earth, which they throw up like moles. These large yellow spots, where vegetation is extinct, which may be remarked in fields and meadows, and the withering of vegetables in gardens, indicate their ravages. It is not, however, in feeding upon the roots of corn, or other plants, that the destruction is effected, for they are not herbivorous, and on the contrary, destroy many noxious insects, but in excavating the galleries of which we have been speaking, they dig under and gnaw the roots of plants, which in consequence wither and die, thus doing an extent of mischief altogether out of proportion with the services which they may render in preying upon other noxious insects. The insect is nocturnal, and it begins to sing or chirp after the setting of the sun or before its rising. Towards the end of October, or beginning of November, they sink into the earth to shelter themselves from the cold, and towards March they come out again.

MODES OF DESTRUCTION.

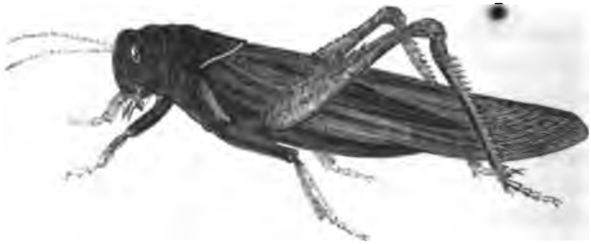
One of the best remedies, though not applied with that intention, is ploughing, for in preparing the furrows, the insects and hundreds of their eggs are destroyed without trouble.

Another remedy, which is stated by Köllar to have been purchased from an artist of Lorraine,by Louis XV., consists in first pouring water into their holes and then a few drops of any sort of oil. They leave their hole when they feel the water, and when touched by the oil die immediately, their spiracles, it is supposed, being stopped by the oil, and the insects being thereby suffocated. This remedy however, we are afraid, does not deserve much reliance, notwithstanding the recommendation of the exalted rank of the original purchaser; to pour water into the hole in order to dislodge the insect, and then to add a few drops of oil to suffocate it, puts one in mind of that mountebank vendor of a flea-powder, the directions for use given by him *after purchase* to the astonished wights being:—"Take the flea by the *scrof* of the neck, drop a little of the powder into its mouth, and the flea will suddenly die!"—"But," said one, "whilst I hold it, I may as well kill it."—Answer, "Either will do."

A more practicable method, which is said to be infallible, consists in digging a pit about two or three feet deep, and one foot wide for every 200 square yards of ground, filling it with horse-dung, and covering it with earth. After the first frost, all the mole crickets in the neighbourhood will collect there to shelter themselves from the cold, where they may be destroyed in heaps. (See *Köllar's Treatise on Insects.*) It is asserted that the use of rape or linseed cake as manure is fatal to mole crickets. The natural enemies of the mole crickets are birds, ants, and other insects.

THE LOCUST, OR MIGRATORY LOCUST,

(*Gryllus migratorius*, Linnæus; *acridium migratorium*, Geoffroy.)



The locust is perhaps the most pernicious of all insects; in the East they multiply in an enormous degree, and spread devastation and famine wherever they chance to alight.

In this country the ravages of these insects are fortunately but seldom felt, as they scarcely ever appear in sufficient numbers to do much damage, but in the Levant and in Africa they frequently invade the lands in such countless numbers, as to become an irresistible scourge.

Cuvier, in his "Animal Kingdom, translated by Mr. Edward Griffith," gives the following description of the locust:—

"This is the insect, whose ravages have been the theme of naturalists and historians of all ages, and upon a close examination, we find it peculiarly fitted and furnished for the execution of its office. It is armed with two pairs of very strong jaws, the upper terminating in short, and the lower in long teeth, by which it can both lacerate and grind its food. Its stomach is of extraordinary capacity and powers—its hind legs enable it to leap to a considerable distance, and its ample vans are calculated to catch the winds as sails, and so as to carry it sometimes over the sea.

Although a single individual can effect but little evil, yet when the entire surface of a country is covered by them, and every one makes bare the spot on which it stands, the mischief produced may be as infinite as their numbers."

The first record of the ravages of locusts which we find in history, is the account in the book of Exodus, of the visitation to the land of Egypt. Africa appears to have been most generally the quarter of the globe most severely subjected to the inroads of the locust tribe. A law was enacted and enforced in the neighbourhood of Cyrene, according to the account of Pliny, by which the people were obliged to destroy these insects in the egg, in the larva state, and in the imago "or state of perfect insect." A similar law prevailed in the island of Lemnos, where each person was forced to furnish annually a certain quantity of locusts. According to Orosius, anno mundi 3800, the north of Africa was so infested by them, that every vestige of vegetation vanished from the face of the earth. After this, he adds, they flew off to sea and were drowned, but their carcases being cast upon shore, emitted a stench equal to what might have been produced by the dead bodies of one hundred thousand men. We are told by St. Augustine, that a pestilence arising from the same cause, destroyed no less than 800,000 people in the kingdoms of Numidia, and many more in the countries along the sea coast.

Blown from that quarter of the globe, the locusts have occasionally visited both Italy and Spain. The former country was severely ravaged by myriads of those desolating intruders, in 591, A.C. These were of a larger size than common, as we are informed by Mouffet, who quotes an eminent historian; and from their stench when cast into the sea, caused a plague which carried off infinite numbers both of men and cattle. A famine took place in the Venetian territory, in 1487, occasioned by the ravages of these insects, in which 30,000 persons are reported to have perished. Mouffet mentions many other instances of the same kind which have taken place in Europe at different periods. They entered Russia in immense divisions, in three different places, in 1600, darkening the air with their numbers, and passed over from there into Poland and Lithuania.

In many parts they lay dead to the depth of four feet. Sometimes they covered the surface of the earth like a dark cloud, loaded the trees, and the destruction which they produced exceeded all calculation. They fall sometimes upon corn, and in three hours will consume an entire field, as happened once in the south of France. When they had finished the corn, they extended their devastations to vines, pulse, willows, and in short, to every thing else wearing the shape of vegetation, not excepting even hemp, which was not protected by its bitterness.

In 1748 considerable numbers of locusts visited this country, but, luckily they did not propagate, and all soon perished. These were stragglers from the swarms which, a year previously, had desolated Wallachia, Moldavia, Transylvania, Hungary, and Poland. An account of this formidable invasion is described in the forty-sixth volume of the Philosophical Transactions as follows :—

" The first swarms entered into Transylvania in August, 1747; these were succeeded by others which were so surprisingly numerous, that when they reached the Red Tower they were full four hours in their passage over that place, and they flew so close, that they made a sort of noise in the air by the beating of their wings against one another. The width of the swarm was some hundreds of fathoms, and its height or density may be easily imagined to be more considerable, inasmuch as they hid the sun, and darkened the sky, even to that degree, when they flew low, that people could not know one another at the distance of twenty paces. But whereas, they were to fly over a river that runs in the vallies of the Red Tower, and could find neither resting place nor food, being at length tired with their flight, one part of them lighted on the unripe corn on this sido of the Red Tower, such as millet, Turkish wheat, &c.; another part pitched upon a low wood, where having miserably wasted the produce of the land, they continued their journey as if a signal had been actually given for a march. The guards of the Red Tower attempted to stop their irruption into Transylvania by firing at them, and indeed when the balls and shot swept through the swarm, they gave way and divided, but having filled up their ranks in a moment, they proceeded on their journey.

"They are of different forms according to the different ages; for when in the month of September some troops of them are thrown to the ground by great rains, and other inclemency of the weather, and thoroughly soaked with wet, they crept along in quest of holes in the earth, dung, and straw, where, being sheltered from the rains, they laid a vast number of eggs, which stuck together by a viscid juice, and were longer and smaller than what is commonly called an ant's egg, very like grains of groats. The females having laid their eggs, die like the silk-worm, and we (Transylvanians) found by experience that that swarm which entered into our fields by the Red Tower, did not seem to intend remaining there, but were thrown to the ground by the force of the wind, and there laid their eggs, a vast number of which being turned up and crushed by the plough in the beginning of the ensuing season, yielded a yellowish juice.

"In the spring of 1748, certain little blackish worms were seen lying in the fields, and among the bushes, sticking together, and collected in clusters, not unlike the hillocks of moles and ants. As nobody knew what they were, so there was little or no notice taken of them, and in May they were covered by the shooting of the corn sown in the winter. But the subsequent June discovered what those worms were, for then, as the corn sown in the spring was pretty high these creatures began to spread over the fields, and became destructive to the vegetables by their numbers. Then at length the country people who had slighted the timely warning given them, began to repent of their negligence, for as these insects were now dispersed all over the fields, they could not be extirpated without injuring the corn.

"At that time they differ little or nothing from our common grasshoppers, having their heads, sides, and back of a dark colour, with a yellow belly, and the rest of a reddish hue. About the middle of June, according as they were hatched, sooner or later, they were generally a finger's length, or somewhat longer, but their shape and colour still continued.

"Towards the end of June they cast off their outward covering, and then it plainly appeared that they had wings, very like the wings of bees, but as yet unripe and unexpanded; and then their body was very tender, and of a yellowish green. Then, in order to render themselves fit for flying, they gradually unfolded their wings with their hinder feet, as flies do. And as soon as any of them found themselves able to use their wings they soared up, and, by flying round the others, provoked them to join them; and thus their numbers increasing daily, they took circular flights of twenty or thirty yards wide, until they were joined by the rest; and, after miserably laying waste their native fields, they proceeded elsewhere in large troops.

"Wheresoever these swarms happened to pitch, they spared no sort of vegetable, they ate up the young corn and the very grass, but nothing was more dismal to behold than the lands in which they were hatched, for they so greedily devoured every green thing thereon before they could fly, that they left the ground quite bare.

"There is nothing to be feared in those places to which this plague did not reach before the autumn, for the locusts have no strength to fly to any considerable distance, but in the months of July, August, and the beginning of September, and even then, in changing their places of residence, they seem to tend to warmer climates."

The gentleman to whom the foregoing account was sent from Transylvania to Vienna, and who transmitted it hither, says, that a considerable number of these locusts had also come within twenty leagues of that city, and that one column of them had been seen there, which was about one hour's journey in breadth, but of such a length that, after three hours, though they seemed to fly fast, one could not yet see the end of the column. The eggs of these animals, which have been preserved in dry mould, have produced nothing; but those which have been preserved in mould that was moistened with water from time to time, gave, early in the spring of 1749, some of these grasshoppers. The little ones were, soon after they came forth, of the size nearly of ordinary flies; they had already the form of grasshoppers, but they had as yet no wings. This observation shows that the author of the foregoing account was mistaken when he says, "these insects had at first the form of grubs or small worms." They change their skin several times, but they do not acquire wings until they have moulted for the last time." (See *Philosophical Transactions*, vol. xlvi. for the years 1749-50, p. 30.)

In the empire of Morocco, the ravages of the locust tribe have been dreadful beyond description: they caused a famine there in 1780. The poor wandered over the country in search of a wretched existence from the roots of plants. They picked from the dung of camels, the undigested grains of barley, and devoured them with eagerness. Numbers perished, and the streets and roads were strewed with carcases.

"When they visit a country," says Mr. Jackson, in his *Travels in Morocco*, "it behoves every one to lay in a provision for famine, for they stay from three to seven years. When they have devoured all other vegetables, they attack the trees, consuming first the leaves, and then the bark. From Mogador to Tangiers, before the plague of 1799, the face of the earth was covered by them. At that time a singular incident occurred at El Araiche. The whole region from the confines of the Sahara was ravaged by them; but on the other side of the river El Kos, not one of them was to be seen, although there was nothing to prevent their flying over it. Till then they had proceeded northward; but on arriving at its banks, they turned to the east, so that all the country north of El Araiche was full of pulse, fruits, and grains, exhibiting a most striking contrast to the desolation of the adjoining district. At length they were all carried by a violent hurricane into the Western Ocean; the shore, as in former instances, was covered by their carcases, and a pestilence was caused by the horrid stench which they emitted; but when their evil ceased, their devastation was followed by a most abundant crop. The Arabs of the Desert, "whose hands are against every man," and who rejoice in the evil that befall other nations, when they behold the clouds of locusts proceeding from the north, are filled with gladness, anticipating a general mortality, which they call *El Khere* (the benediction); for when a country is thus laid waste, they emerge from their arid deserts, and pitch their plants in the desolated plains."

It appears that in many of the instances which have been recorded, these devastating insects must have crossed the seas, though Haselquist asserts that they have no capability of so doing. He says,—"The grasshopper or locust is not formed for travelling over the sea; it cannot fly far, but must alight as soon as it rises; for one that came on board us a hundred certainly were drowned. We observe in the months of May and June a number of these insects coming from the south, and directing their course to the northern shore; they darken the sky like a thick cloud; but scarcely have they quitted the shore when they, which a moment before ravaged and ruined the country, cover the surface of the sea with their dead bodies. By what instinct do these creatures undertake this dangerous flight? Is it not the wise institution of the Creator to destroy a dreadful plague to the country?"

Notwithstanding all this, we have seen that locusts do perform very considerable flights. Much in this way must depend upon their age and species; much also on their strength and point of the winds, for there is no doubt but that a swarm of these insects may be carried by a strong gale over a broad river, or across a narrow sea, nay, even to a considerable distance out to sea."

Fortunately Europe is not much subject to the ravages of these insects, though in the meridional parts of the continent a premium was, and still continues to be, paid for their destruction, at the rate of a quarter of a franc for 2lbs. of these insects, or half a franc for the same weight of its eggs. The way in which the peasants of those parts gather them is by holding a sheet by the four corners, and skimming, as it were, with it the surface of the soil with the edge of the extended cloth, into which the insects jump whilst endeavouring to escape. May is the time for that operation. The female insect deposits her eggs generally in August, but sometimes also in September, or even in October, and it is said that an expert child may gather from 12 to 14 lbs. of eggs per day.

Lizards, frogs, birds, foxes, hogs, &c., are the natural enemies of the locust.

Most of the insects which are injurious to grain are also injurious to meadows.

INDEX.

PAGE.

Acridium migratorium . 206
Agriculture (definition) . 1
Agriotes . . . 175
Agrotis affinis . . 191
    Segetum . . 191
Alucite . . . 184
  Where found, and how destroyed . . . 185
Alum 33
Alumina . . . 25
  How detected in soils . 64, 87
  Proportion of in good soils 26
  (See *Clay*.)
  Ammonia . . . 38
  How detected in soils . 63
  How determined ditto . 71, 78
Ammoniacal salts—
  How detected . . 41, 63
  How determined . . 70
  As manure . . 119
Analysis (qualitative and quantitative . . . 44, 59
  Instructions to perform . 60
Anisoplia . . . 173
Apocrenic acid—estimation of in soils . . . 94
Ashes (quantity left by plants) 19, 23
  Composition of . . 20, 24
Attraction (capillary) . 54
  How determined in soils . 55
Beetle (gibbous ground) . 187
  How destroyed . . 191
Blight (see *Mildew*) . 145
Black blight (see *Smut*) . 151
Black corn (see *Smut*) . 151
Black mildew (see *Smut*) . 151
Blood (as manure) . . 105
Blue clay . . . 32
Bogs . . . 13, 18
Bone ashes . . . 38
Bones . . . 37
  As manure . . 106
Bran (as manure) . . 101
Brand bladders (see *Canker*) 159

PAGE

Brimstone (see *Sulphur*) . 33
Capillary attraction (see *Attraction*) . . . 54
Calandra granaria . . 177
Canker . . . 159
  Plants most liable to . 160
  How detected . . 161
  Remedies . . . 163
Carabus auratus . . 173
    gibbus . . 187
Carbonate of ammonia . 35
  Decomposed by plaster . 39
  How detected in soils . 66
  How determined ditto . 76
  As manure . . 120
Carbonate of lime . . 26
  How detected . 27, 65, 86
  Its proportion in soils . 48
  How determined . . 79, 89
Carbonate of magnesia . 29
  How detected . . 30
Carbonate of potash . . 66
  How determined . . 76, 82
  As manure . . 122
Carbonate of soda . . 66
  How determined . . 76, 82
  As manure . . 122
Carbonic acid . . 42
  How detected . . 66, 87
  How determined . . 74
Cataphagus . . . 175
Caustic lime . . . 26
    magnesia . . 29
Cecydonia tritici . . 199
Chalk (see *Carbonate of Lime*) 26
Chloride of calcium—how detected in soils . . 63
  How determined . . 73, 79
Chloride of magnesium—how detected in soils . . 63
  How determined ditto . 73, 81
Chloride of potassium—how detected in soils . . 63
  How determined ditto . 73, 82

PAGE.
Chloride of sodium . . 36
  Action of—on soils, and how detected . .37,63
  How determined . . 73
  As manure . . . 122
Chlorine, how detected . 63
  How determined . . 73
Chlorops pumilionis . . 193
Churr worm (see *Mole Cricket*) 203
Classification of soils . 14,16
  How to refer a given soil to its class . . 49
Clays (effect of, on soils) see *Alumina* . . . 7,26
  Blue 32
  How determined in soils . 47
Cockchafer . . . 171
  Where found, and how destroyed . . . 172
Composts 115
Copperas, green (see *Sulphate of Iron*) . . . 33
Corn moth . . . 182
Corn weevil . . . 177
  Where found, and how destroyed . . . 179
Corn worm . . . 182
Crenic acid, estimation of in soils 94
Curculio granaria . . 177
Dart (common) . . 191
Diseases of cereals . . . 145
Dolomite 29
Dust brand (see *Smut*) . 151
Earth crab (see *Mole Cricket*) 203
Elater lineatus . . 175
Epsom salts . . . 33
Ergot 165
  Soils most favourable to production of . . 166
  How detected, and remedies 166
Excrements (as manure) . 107
  Analysis of . . . 108
Eve churr (see *Mole Cricket*) 203
Farm-yard manure . . 114
Feathers (as manure) . 105
Field cockchafer . . 173
Filters 60
Filtering (precautions in) . 73
Flesh (as manure) . . 104
Food of plants . . 2, 97
Geic acid (estimation of, in soils) 94

PAGE.
German cockchafer . . 173
  Where found, and how destroyed . . . 174
Glass (common and soluble) 28
Glauber's salt . . 33
Granary (Demarçay's) . 186
  (Moveable) . 180
Green vitriol (see *Sulphate of Iron*) 33
Grub 171
Gryllus gryllotalpa . . 203
  migratorius . . 206
Gryllotalpa vulgaris . . 203
Guano 113
  Analysis of . . 124
Gypsum (see *Sulphate of Lime*) 33
Hairs (as manure) . . 105
Harpelidus tardus . . 187
Hoofs (as manure) . . 105
Humic acid (estimation of) . 94
Humine 43
Humus 4.41
  How determined in soils . 47
Insects injurious to cereals . 168
Jarr worm (see *Mole Cricket*) 203
Leaves 101
Limax agrestis . . 174
Lime plants . . . 23
Lime (quick) . . 26
Lime-stone (see *Carbonate of Lime*) 26
Lined click beetle . . 175
Linseed cake . . . 102
Locust 206
Loamy soils 26
Magnesia 29
  How detected . . 65,86
  How determined . . 80
Manganese (see *Oxyde of Manganese.*) . . 99
  Analysis of . 124
  Green, soils most benefited by 99
  Animal . . . 103
  Comparative value of . 140
  Farm-yard . . . 114
  Mineral or saline . . 99
Marl 28
Marshes 13
Melolontha agricola . . 173
  Vulgaris . . 171
Mildew 145

PAGE.

- Mildew, how detected 147
  - Soils favourable to the production of 149
  - Remedies 150
- Mole cricket 203
  - Where found, and how destroyed 204
- Mould 4
- Muriate of soda (see *Chloride of Sodium*) 36
- Musca pumilionis 193
- Nitrates (how detected in soils) 67
- Nitrate of ammonia, as manure 119
- Nitrate of lime (how determined) 79
- Nitrate of potash 82
  - As manure 121
- Nitrate of soda 82
  - As manure 121
- Nitric acid (how detected in soils) 67
- Noctua segetis 191
- Normandy's gas furnace 90
- Oil of vitriol (see *Sulphuric Acid*) 33
- Organic matter 41
  - How detected in soils 43,47,68,70
  - Undecomposed (how to estimate its quantity in soils) 95
- Oscinis pumilionis 193
- Oxydes of iron 31
- Oxyde of manganese 32
  - How detected in soils 64,86
  - How determined 80
- Pepper brand (see *Canker*) 159
- Peroxyde of iron 31
  - How detected 32, 64, 85
  - How determined 78,89
- Phosphates 37
  - How detected in soils 68
- Phosphate of lime 19, 38
- Phosphoric acid (how detected in soils) 68,86
  - How determined ditto 83
- Phosphorus 37
- Plants—
  - Food of 2
  - Growing spontaneously in clayey soils 5
  - Ditto on chalky soils 9
  - Ditto on marly soils 8
  - Ditto on sandy soils 10
  - Ditto on humous soils 12

PAGE.

- Plants, quantity of ashes left by 20
  - Potash plants, lime plants, silica plants 23
- Plaster (see *Sulphate of lime*) 33
- Potash (how detected) 66,86
  - How determined 82
- Potash plants 23
- Poudrette 111
  - Composition of 112
- Precipitate (caution in washing) 74
- Peroxyde of iron 31
  - How detected 32-85
- Quick lime 26
  - Its use 27,29
- Rape cake 102
- Rham's specific gravity bottle 57
- Red rust (see *Mildew*) 145
- Rust 31
- Sand (see *Silica*) 28
- Sandy marls 28
- Sal ammoniac 38
  - As manure 119
- Salt, common (see *Chloride of Sodium*) 36
- Sea weeds, as manure 100
- Sewage water, as manure 111
- Silica 28
  - How detected in soils 46 ,64, 85
  - How determined in soils 77,87
- Silica plants 23
- Silicate of alumina 87
- Silicate of iron 87
- Silicate of lime 89
- Silicate of potash 29
- Skins (as manure) 105
- Slugs 174
  - Where found, and how destroyed 175
- Smelling salts (see *Carbonate of Ammonia*) 39
- Smut 151
  - How detected 152
  - Remedies 159
- Smut balls (see *Canker*) 159
- Soda (how detected) 65,86
  - How determined 82
- Soot 151
- Soils (how formed) 3
  - Principal ingredients of 4, 17
  - Various sorts of 5
  - Plants which grow spontaneously on 6

PAGE.
Soils—
Marly 7
Chalky 8
Light or sandy . . . 10
Relative proportions of the elements of . . . 11
Humous 12
Classification of . . 14, 16
Constituents of . . . 17
How recognized . . . 44
Ingredients of, most important 45
Boggy or peaty . . 18, 43
Loamy 26
Power of absorbing water . 56
Capillary attraction of . 53
Cause of sterility of, and remedy thereto . . 98
Specific gravity . . . 49
Methods of taking . . 50
Table of 52
Spur (see *Ergot*) . . 165
Subsoils (how formed) . 3
Sulphate of ammonia, (how detected in soils) . . 63
As manure . . . 119
Caution in purchasing . 120
ulphate of iron . . 33
Its effects on plants . 36
How recognized . . 36
How detected in soils . 63
How determined in soils . 72
Sulphate of lime . . 33
Precaution when given as special food to plants . 34
Decomposed by carbonate of ammonia . . 35
Action of, on soils . . 35
How detected in soils . 35
How determined in soils . 72, 79
As manure . . 123

PAGE.
Sulphate of Magnesia . 33
How detected in soils . 63
How determined in soils . 72, 81
As manure . . 124
Sulphate of potash . . 33
How detected in soils . 63
How determined in soils . 72, 82
Sulphate of soda . . 33
How detected in soils . 63
How determined in soils . 72-82
As manure . . 123
Sulphur . . . 33
Sulphuric acid . . 33
How detected in soils . 63, 84
How determined in soils . 72, 88
Sulphurous acid . . 33
Tinea Granella . . 182
Tipula tritici . . 199
Ulmic acid, estimation of in soils 94
Ulmine . . . 43
Urine (as manure) . . 112
How to fix the ammonia of 113
Volatile matter (how determined in soils) . . 70
Water (hard and soft) . 34
Determination of in soils . 45
How to determine the retaining power of soils for water 55
How to determine the absorbing power of soils for water . . . 57
Washing bottle . . 74
Wheat fly . . . 193
Where found, and how destroyed . . . 198
Wheat midge . . 199
How destroyed . . 201
Wire worm . . 175
Where found, and remedies 177
Zabrus Gibbus . . 187

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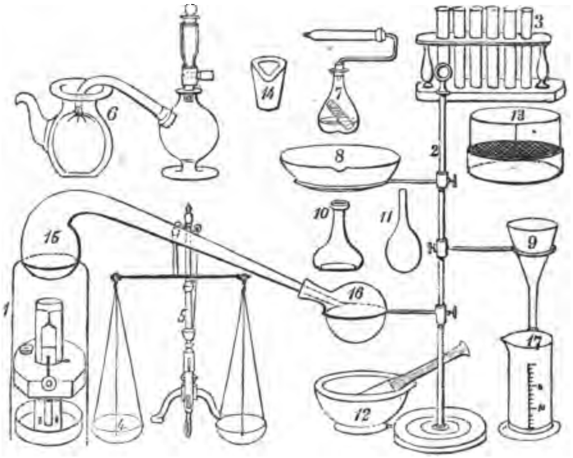

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